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THE FATE OF TRANSPLANTED BONE AND REGENERATIVE POWER OF ITS VARIOUS CONSTITUENTS

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BONE may be transplanted experimentally for the purposes of determining (1) its value as a reparative agent in bony defects, and (2) the viability and regenerative powers of its constituent parts. In the investigations which I have carried on, the viability and regenerative powers have been studied not only in bony tissues which were used for the repair of bony defects, but also in those which were transplanted into the soft parts, since conditions of function and in some instances of nutrition differ in the two locations. All of the experiments were performed upon dogs with bone from the same animal, as it has been sufficiently proved that bone from a different animal of the same species behaves in the same manner as that from the same animal, but with somewhat diminished powers, and that a transplant from a different species acts the same as dead bone or any other foreign body. In both series the experiments have been arranged in groups according to the composition of the transplant, which was varied as follows: bone plus periosteum and endosteum, bone minus periosteum, bone minus both periosteum and endosteum, boiled bone, and periosteum alone.

An extensive review of the literature has not been attempted owing to the fullness with which it has been given in a number of recent contributions upon the subject. Particular reference may be made to the works of Axhausen, Wieder, Frangenheim, Macewen, McWilliams, Cotton and Loder, and Mayer and Wehner, where the various workers in this field have been accredited with their contributions to the subject. Findings at variance with the views held by certain authors will be mentioned from time to time. The two sets of experiments will be considered separately.

BONE TRANSPLANTED INTO A BONY DEFECT

When a defect in the course of a long bone is filled in by a transplant, nature is confronted with three tasks to perform, namely:

I. The preservation of nutrition and reestablishment of circulation of the transplant.

II. The union of the ends of the transplant with the ends of the fragments.

III. The transformation of the transplant into a duplicate of the normal bone whose place it fills.

An analysis of the experiments based upon these three considerations will first be made, after which a detailed description of each will be given under a purely anatomical classification.

I. THE PRESERVATION OF THE NUTRITION AND REËSTABLISHMENT OF THE CIRCULATION OF THE TRANSPLANT

This is the most important of the three considerations, for upon its success or failure

is dependent, to a considerable extent, the outcome of the other two. From the standpoint of technique the conditions most favorable for the preservation of the life of the cells and the reëstablishment of the circulation are perfect hæmostasis, perfect asepsis, and perfect coaptation of transplant and soft parts. The presence of a blood-clot about the transplant interferes with its early and free permeation by serum, which for a time is the only source of nutrition. It also delays the reëstablishment of a blood vascular circulation by preventing an early organic union between the soft parts and the transplant. Infection is particularly apt to result in death of the transplant. That this is not always the case, however, is shown in some of the experiments, and the effects of a mild infection will be dealt with later on. From the standpoint of the transplant itself those cells about the surface and about the ends of the medullary cavity are in the most favorable position to receive nutrition both from serous permeation and from the early ingrowth of capillaries from the surrounding parts, while the cells of the compact bone, haversian canals, and medullary cavity away from the periphery occupy a very unfavorable location. There is also a great difference in the nature of the different cells. The unossified portions of the transplant, i. e., the periosteum and contents of the medullary canal, porous spaces, and haversian canals, being loose in structure, are readily permeable to lymph and consequently more apt to live. However, the bone-cells, lying in small lacunæ surrounded by a very extensive matrix in which there is a dense deposit of calcium salts, and communicating with each other by and receiving their nutrition through long, small, and tortuous canaliculi, present one of the most difficult situations that can be offered for the restoration of a cut-off nutrition. This difficulty of penetration is well illustrated by the fact that more time is required for a fixing fluid to fix a piece of bone than for a piece of soft tissue of equal size; also in decalcification by the marked delay of the process in the central portion of the bone. Degree of cell specialization also plays a part. The blood-forming elements of the marrow, and to a slight extent the ossified cells, are more highly specialized than the rest; consequently, they are more apt to suffer from interference with the supply of nutrition. Where the technique was properly carried out the influence of these factors upon the different types of transplant was noted.

1. *Transplant plus periosteum and medullary contents.* In fourteen experiments ranging in age from 3 to 350 days the most ideal conditions were reproduced. Sections of the lower third of the ulna varying in length from one-half to one and one-half inches were excised and reimplanted with periosteum and contents of the medullary cavity intact. The results were as follows:

(a) The periosteum and fibrous tissues of the ends of the medullary canal receiving sufficient nutrition and early restoration of blood-vessels, live and retain their proliferative and regenerative powers.

(b) The hæmopoietic cells of the bone-marrow, regardless of their somewhat favorable conditions for nutrition, after retaining vitality for ten or twenty days gradually undergo necrosis and absorption. The medullary canal becomes filled with callus at its ends and with a pale-staining fibrous tissue throughout the rest of its extent.

(c) The vessels of the haversian canals undergo necrosis. In spongy portions the fibrous contents of some of the spaces located about the periphery remain alive and take part in the regenerative process. The entire haversian system is restored by an ingrowth of vessels from the periphery. In case of the deeply situated small canals in a very thick cortex, several weeks or months may be required for revascularization.

(d) The bone-cells, except for a small number about the surfaces of the cortex, porous spaces, and larger haversian canals, undergo necrosis and absorption. These changes occur rather slowly. At the end of three or four days the cells all appear alive. By the tenth day about one-half have either disappeared or their nuculei are shrunken or stain poorly. At the end of a month the vast majority of lacunæ are empty and the remaining cells show degenerative changes. A few necrotic cells may persist for fifty or

seventy-five days before being absorbed. This persistence of bone-cells is to be explained in two ways: some of them get sufficient nutrition to maintain a feeble vitality for an indefinite period, while other more centrally located and inaccessible necrotic cells persist because of the difficulty with which they are absorbed by the permeating serum. This same delayed absorption of inaccessible cells is sometimes seen in transplanted boiled bone where the nuculei have been fixed by heat, and in sequestra due to tuberculosis.

In four experiments ranging in age from 10 to 84 days the excised segment was split longitudinally and one-half of it used as the transplant, the medullary surface being exposed throughout its entire length. Conditions in the cortex and periosteum were the same as in the preceding series, but the endosteum and fibrous tissue of the marrow being more favorably located for the reception of nutrition remained alive and proliferated throughout the length of the canal.

2. *Transplant minus periosteum.* In seventeen experiments ranging in age from 6 to 348 days periosteum was removed from the excised segment before reimplantation. The results in the remaining tissues were practically the same as in those of the first series. Very few ossified cells along the periosteal surface remained alive, despite the fact that absence of periosteum made nutrition more accessible. Wherever the periosteum was imperfectly removed its remaining cells proliferated and formed islands of callus.

3. *Bone minus periosteum and endosteum.* In three experiments, 21, 46, and 75 days old respectively, the transplant consisted of a strip of bone from the crest of the tibia with both periosteal and endosteal surfaces whittled off, giving it the appearance of an ivory peg. There was necrosis and absorption of all of its cells except those lining a few of the porous spaces scattered along the medullary surface and a few about the periosteal surface. These scattered surviving cells gave rise to some callus formation, particularly at the ends where fragments and transplant were in contact, as will be seen in the subsequent analysis. In three experiments, 9, 27, and 55 days old a segment of radius one inch long was excised, periosteum and endosteum removed, and the cortex cut into ten or fifteen pieces which were reimplanted into the defect. Some of the cells of the splinters lived and gave rise to callus formation which surrounded them and which united with the callus from the ends of the fragments to restore the continuity of the shaft. However, the great bulk of the bone-cells of the splinters underwent necrosis and in the fifty-fifth-day experiment had been absorbed while some substitution of the necrotic portion had begun.

4. *Transplant consisting of periosteum.* Periosteum completely detached was transplanted into the bony defect in four experiments, 10, 41, 70, and 139 days old respectively. In every instance periosteum remained alive and formed an incomplete fibrous band connecting the ends of the fragments, but in no case did it lead to new bone formation and regeneration of the shaft.

Thus we see that in bone transplantation it is almost entirely the non-osseous portions, i. e., the periosteum, endosteum, and fibrous tissue of the ends of the medullary canal, that survive the marked interference with nutrition to which they are subjected, and later constitute the living portion of the transplant from which its regeneration largely takes place. However, that the vitality of these portions does not remain unimpaired will be shown later by the fact that in the healing of the two fractures at either end callus formation is less marked from them than from the periosteum and endosteum of the ends of the fragments.

II. UNION OF THE ENDS OF THE TRANSPLANT WITH THE ENDS OF THE SHAFT

This process is analogous to the healing of two fractures and is accomplished by proliferative changes leading to callus formation, not only from the tissues of the ends of the shaft, but also from those tissues of the ends of the transplant which survive the transplantation. In order to obtain the surest and most rapid union between the ends there are two factors of great importance aside from favorable conditions of nutrition in the parts to be united. These are perfect coaptation

and perfect immobilization. When perfect coaptation is obtained a small amount of callus is formed, and the smaller the amount of callus the more rapid is its transformation into bone. Also, when the approximation is good there is considerable stress thrown upon the bone, and the ends of the transplant and fragment are forced against each other from the tension exerted by the soft parts of the extremity. In other words, under these circumstances the bone early resumes a part of its function, which resumption of function is a powerful stimulus to the osteogenetic tissues both of the transplant and ends of the fragments to repair the existing defects in continuity of the bone. Perfect immobilization is essential because mobility both increases the size of the callus and traumatizes its intermediary portion, causing hæmorrhage and serous accumulation between the ends and consequently, delay in the process of ossification. The mechanism of fixation may be of two kinds: either an external appliance in the shape of a splint or plaster of Paris dressing, or an internal arrangement whereby the fragments and the transplant are held directly together. The latter method may be accomplished in man by suturing or plating, by the inlay method of Albee, or, best of all, by impaction of the ends of the transplant into the medullary canal of the ends of the fragments, a method which has been so extensively carried out and perfected by Murphy. As much internal fixation should be obtained as possible because partial immobilization and partial support of the limb by the transplant itself acts as a stimulus for osteogenesis on the part of its surviving cells. In working upon small bones of the dog the above methods of fixation are impracticable; and the transplants in these experiments were simply wedged into the defects, frequently with considerable angulation and imperfect coaptation with the ends of the fragments. It was in the imperfectly performed experiments that the above-mentioned results from faulty technique were observed.

Before further discussion of the method by which union occurs between the ends of the fragments and transplant, it is advisable to review briefly the healing of a simple fracture. This occurs by the formation of a callus from the two ends of the bone, which callus bridges over the defect. It consists of three portions, i. e., periosteal, medullary, and intermediary, and goes through three periods of transformation: the period of fibrous callus formation, the period of ossification, and the period of reduction and consolidation. There is considerable overlapping of these periods, but this is the order in which they occur. Fibrous callus formation comes first and all three portions go through this stage.

The periosteal callus forms almost entirely by a proliferation of the inner or cambium layer of the periosteum. The more superficial bone-cells may decalcify and multiply, as may also the cells of Volkmann's canals, but their part in the formation of callus is a very minor one. It begins to form within the first twenty-four hours, and reaches its maximum size at the end of the second week.

The medullary fibrous callus forms from a proliferation of the endosteum and fibrous tissue of the ends of the medullary canal filling it for a distance of one-half to two centimeters in either fragment. Its formation is complete as a rule by the tenth day.

The intermediary fibrous callus forms last from an ingrowth of the periosteal and endosteal callus of the fragment ends, taking the place of the blood-clot which primarily fills in the space. None of this callus comes from the fractured surfaces of the fragment ends. The bone-cells of the ends of the fragments for a distance of one-third to one-half centimeter undergo necrosis and absorption as a result of interference with their blood supply. The period of ossification greatly overlaps that of fibrous callus formation, beginning two or three days after the first callus is laid down and continuing for three weeks to several months before the process in the intermediary callus is complete. Ossification always begins on the surface of the bone and extends gradually to the more distant portions of the callus. In the medullary portion it occurs by direct transformation of the fibrous cells into bone-cells without an intermediary cartilaginous stage. It always begins on the wall of the canal and extends gradually to the central portion of the callus,

being complete first toward the very end of the canal. Ossification is, as a rule, complete in twelve to sixteen days. This early bony callus is very spongy and imperfectly formed. In the periosteal callus the process is different. Early ossification along the surface of the cortex is by the direct transformation of fibrous into bony cells, but after four or five days when the callus has reached considerable dimensions a zone of cartilage increasing in thickness toward the intermediary callus usually appears in front of the zone of ossification. As ossification proceeds this zone of cartilage gradually approaches the surface, shortens toward the seat of fracture, and finally passes over entirely into the intermediary callus. Ossification of the cartilaginous zone occurs largely by metaplasia or the direct transformation of cartilage-cells into bone-cells, but to some extent, particularly when the amount of cartilage is large and the process is delayed, by the enchondral method or death of cartilage-cells with substitution by the ingrowing bone. The intermediary callus is last to undergo ossification. It begins along the edges within a few days and requires from two or three weeks to months for its completion. Early ossification comes from only two sources. That portion which originates from the medullary canal ossifies by extension of the process from the medullary callus, and the outer or periosteal portion by an extension from the ossifying periosteal callus. After three or four weeks, ossification begins on the fracture surfaces from an outgrowth of capillaries and osteoblasts which have refilled the haversian canals of the ends.

Dimunition in size and consolidation of the callus with rearrangement of its trabeculæ and restoration of the lumen of the medullary canal are slowly accomplished in the subsequent months, but since they throw no light on osteogenesis they will be given no further consideration. This, in general, is the process of repair which has been noted by all investigators, as Wieder, Curnil and Coudray, Zondek and Zeigler, who have made extensive microscopic studies. My observations have confirmed these findings not only in this series of experiments but also in thirty simple comminuted fractures in which the fate of detached fragments of bone was studied.

To recapitulate briefly, the fibrous callus originates almost entirely from a proliferation of the inner or cambium layer of the periosteum, and from the fibrous tissue of the medullary canal. It undergoes ossification by the transformation of its cells into bone-cells. Hence we must say that these are osteogenetic tissues. This is entirely in accord with findings in the study of the development of the osseous system. The long bones are preformed in cartilage which is surrounded by a primitive periosteum. Ossification occurs by the growth into the cartilage of buds composed of blood-vessels and fibroblasts from the inner layer of periosteum. These cells or osteoblasts give rise to bone which takes the place of the cartilage. The periosteum continues to play an important rôle throughout the entire period of bony growth. In the event of a fracture at any period of life, where the demand for new bone formation is great the periosteum reverts to its early characteristics and shows marked osteogenetic properties. The statement of Macewen and others that callus forms from bone-cells only and not from the inner unossified cells of the periosteum is based upon *a priori* conclusions and not at all upon microscopical studies of experiments.

When we study the method by which union occurs between a transplant and a fragment we find that it is very similar to the healing of a simple fracture. The chief differences are that callus formation from the periosteum and endosteum of the transplant is not so vigorous as that from the periosteum and endosteum of the end of the fragment, and that bony union requires a very much longer time in which to occur. These are due chiefly to the fact that the surviving cells of the transplant suffer nutritional disturbances which are sufficient to diminish their osteogenetic powers.

1. In seven experiments ranging in age from 3 to 350 days a section of the ulnar shaft was excised and reimplanted with periosteum intact. In general, a spindle-shaped callus formed at the seat of either fracture which had its origin from the periosteal and medul-

lary contents of the ends of both transplant and fragments. In nearly all of the experiments where periosteal callus still persisted it was present in greater amounts on the end of the fragments than on the transplant. Medullary callus was always more extensive in the ends of the fragments than in those of the transplant. Union was much slower than in the healing of a simple fracture, particularly at the end of the transplant nearer the middle of the shaft. Inspection of the protocols shows in Experiment 105, 26 days old, both fractures united by a fibrous intermediary callus. In Experiment 106, 51 days old, there is bony union of the lower fracture, but a fibrous intermediary callus at the upper end. In Experiment 107, 132 days old, there is bony union at the lower end, but at the upper end a thin zone of the intermediary callus is still fibrous.

In four experiments from 10 to 84 days old the excised section was split longitudinally and one half was reimplanted. Callus formation and metamorphosis occurred the same as in the first group of experiments except that the medullary callus from the transplant was more abundant and blended with that from the periosteum of the fragment.

2. In six experiments from 10 to 119 days old, periosteum was left on the transplant but cut from the ends of the fragments. A callus formed at the seat of each fracture which in its periosteal portion was of the usual size on the end of the transplant but was usually very small on the denuded ends of the fragments, the latter being covered by a layer of fibrous tissue. In some instances callus developed from the periosteum back of the denuded surface and grew down over it, while in others islands of callus formed where periosteum was apparently incompletely removed (Experiment 138). But in the older specimens some peripheral bony callus developed from the cortex of the denuded ends. Callus formation in the medullary canals of both transplant and fragment was the same as in Series No. 1. Bony union is slightly *en retard* of that in the first series as shown by Experiment 139 R where both intermediary calluses are fibrous at the end of 61 days.

3. In seven experiments from 10 to 87 days old, periosteum was removed from the transplant. In general, the periosteal callus at the fractures was of the usual amount from the ends of the fragments, but very much smaller from the ends of the transplant. Medullary callus formed in the ends of both transplant and fragments but was more extensive in the latter. Bony union was delayed more than where periosteum was left on the transplant, as will be seen from Experiment 173 L, 87 days old, and Experiment 119, 118 days old, where the intermediary calluses are still partly fibrous, allowing mobility at both ends.

4. In nine experiments from 6 to 348 days old, periosteum was removed from both transplant and ends of fragments. In all of these experiments periosteal callus formation at the fractures was very small from the ends of both transplant and fragments. Medullary callus formed in the ends of the canals and gave rise to nearly all of the intermediary callus. Ossification of the medullary callus occurred early and in the regular way, but was very much retarded in the intermediary callus. There was a very small amount of ossification in the scanty peripheral callus which was present. Bony union was delayed longer in this than in any other set of experiments. In Experiments 144 L, 199 days old, 143 R, 293 days old, and 143 L, 348 days old, complete bony union occurred at only one end of the transplant. Removal of the periosteum lessened the size of the peripheral callus and delayed very markedly the process of bony union.

5. In three experiments, 21, 46, and 75 days old respectively, the transplant consisted of a piece of cortex from the crest of the tibia with both periosteal and endosteal surfaces whittled off. In all three experiments there was fibrous union with free mobility at either end. The callus from the fragments was of the usual size and ossified in its periosteal and medullary portions. From the ends of the transplant there was a small fibrous callus with a small amount of ossification in its inner portion along the surface of the bone. The intermediary callus was entirely fibrous except in the oldest experiment where ossification was beginning from the ends of the shaft.

These experiments show that transplanted bone devoid of periosteum and endosteum contains a few surviving cells which result in a certain amount of callus formation at its ends and which participate in the repair of the two fractures. The regeneration from small pieces, which is more extensive because of the increased surface and greater facility for nutrition, was previously noted.

6. One of the most convincing evidences of the great rôle played by periosteum in the healing of fractures is seen in the union of a fracture through the middle of a transplant. In three experiments, 25, 35, and 45 days old respectively, the periosteum was left on the fractured transplant. Good approximation and slight impaction of these fractures was obtained before reimplantation. In each instance a spindle-shaped callus formed at the seat of fracture in the transplant as well as at the two ends. In the 25- and 45-day experiments it had undergone bony transformation and union was firm while mobility was present in the fractures at either end, both intermediary calluses of which were fibrous (see Experiment 186 R, Fig. 7, Frontispiece). This rapid bony union of the fracture through the transplant while that at either end remained fibrous was due to the better approximation and immobilization obtained by impaction. In the experiments where periosteum was removed there was no spindle-shaped periosteal callus at the seat of the freely movable fracture in the transplant, and union in the 90-day experiment was by a fibrous intermediary callus in which only a small amount of ossification was present (see Experiment 173 L, Fig. 8). This proves conclusively that the callus which united the fractures through the transplant in the first series of experiments had its origin almost entirely from the periosteum.

There is usually considerable difference in the processes of ossification at the two ends of the transplant. Larger callus formation and much later bony union nearly always occurs at the end nearer the middle of the shaft, which in these experiments was the upper one. There are two reasons for this: one is the better immobilization of the fracture nearer the end, which was quite decided, as the ulna was cut off just above the epiphysis, leaving the lower fragment firmly attached to the lower end of the radius. The end toward the middle is not so firmly fixed; consequently, movement and displacement are more apt to result. The other reason is that the cortex is thicker toward the middle than at the ends and it is a well-known fact that delayed union is commoner in fractures of the shaft with a thick cortex and narrow medullary canal than in those of the epiphysis with a thin cortex and a larger canal filled with spongy bone from which bony callus formation rapidly occurs.

III. TRANSFORMATION OF THE TRANSPLANT INTO A DUPLICATE OF THE NORMAL BONE WHOSE PLACE IT FILLS

This is a purely compensatory change. The transplant is called upon to perform the function of the missing bone, which it will do more nearly if its form, size, and structure are changed to that of the missing portion. In case the defect is filled in by the unaltered excised portion, as in some of these experiments, no alteration in form will be necessary except that demanded by any malposition of fragments; but where a transplant of different size and shape is used, transformation will be called for in proportion to the degree of variation. An internal transformation is also brought about by the nutritional disturbances resulting in death of nearly all of the bone-cells. The living cells of the transplant proliferate and form new bone which gradually takes the place of the dead portions. Blood-vessels and osteogenetic cells from the surviving peripheral portions gradually grow into and dilate the haversian canals, depositing circumferential lamellæ of new bone as the old is absorbed. This is the so-called "creeping substitution" of old bone by the new, which process continues until all of the dead cortex is replaced, requiring from three months to a year or more for completion, depending upon the size and density of the transplant. The surviving superficial portions which bring about this transformation are the periosteum, endosteum, and some of the bone-cells.

1. In those experiments where periosteum and endosteum were left on, substitution of

the dead cortex by new bone occurred most rapidly because the transplant contained the greatest amount of living osteogenetic tissue. In Experiment 105, 51 days old, about one-fifth; in Experiment 107, 132 days old, about one-half; and in Experiment 113, 350 days old, all of the old dead bone had been substituted by new.

2. In those experiments where periosteum was removed and substitution occurred from the living osteogenetic cells of the endosteum and surface of the bone, transformation was slower than where periosteum was left on. Thus, in Experiment 173 L, 87 days old, only a very small amount; in Experiment 144 R, 64 days old, about one-third; and in Experiment 143 L, 348 days old, five-sixths of the old bone had been replaced by new.

3. Where both periosteum and endosteum were removed and the surface whittled away, there were only a few surviving cells from which osteogenesis and transformation could occur. Unfortunately, there were no old experiments in this group, the oldest one being 75 days. In it there was a small amount of callus formation at either end of the transplant and a trace of new bone in some of the superficial porous spaces without any definite evidence of substitution. Because of the small amount of osteogenetic tissue present and the absence of substitution in this case it is safe to say that transformation into new bone would be proportionately delayed in older transplants. Where the transplant was cut up into small fragments, as in Experiment 181, callus formation was more abundant but the cells of the interior died and were absorbed which meant eventually a transformation of the dead cortex.

In those experiments where the excised portion was split longitudinally and only one-half was reimplanted, marked osteogensis occurred on the part of the endosteum with the formation of new bone throughout the entire length of the medullary canal, which rounded off the transplant into a cylinder giving it the shape of the original bone whose place it filled. (See Experiment 153, 64 days old.) The process of transformation approaches completion as the experiment increases in age.

4. In five specimens ranging in age from 10 to 200 days, the excised portion was boiled before reimplantation. It became surrounded by a fibrous covering and some absorption of the dead cortex occurred. A fibrous union formed at either end, but in none of the specimens was there, as yet, any substitution by the ingrowth of new bone from the ends of the fragments.

ANATOMICAL CLASSIFICATION OF EXPERIMENTS

The experiments, except where otherwise specified, were performed upon the lower portion of the ulna and consisted in reimplantations of part or all of the excised portions treated according to the series to which they belong. For convenience of description the reimplanted bone will be spoken of as the transplant and the points of contact of its ends with the fragments as the upper and lower fractures.

I. TRANSPLANT WITH PERIOSTEUM INTACT

I. Transplant with periosteum and endosteum intact; ends of the fragments intact.

a. Entire segment of shaft reimplanted.

3 day experiment. No. 109. Transplant two-thirds inch long.

Examination shows considerable extravasation of blood in the soft parts about the transplant; fractures bridged over and transplant surrounded by blood-clot out of which the transplant is easily lifted. There is a slight swelling of the periosteum at the end of the fragments, but none of the transplant. Transplant and ends of fragments decalcified and sectioned *en masse*. Microscopic examination shows that the clot surrounding the transplant and filling in the gaps at the seats of fracture consists largely of a fibrinous network. The medullary canal of the ends of the fragments and transplant is filled with blood. Neither the periosteum nor the bone-cells of the transplant show any changes. There is a small amount of blood extravasation beneath the periosteum of the ends of the fragments and beginning proliferation of the inner layer of the periosteum.

10 day experiment. No. 113. Transplant two-thirds inch long.

Good approximation with ends of fragments. Small spindle-shaped periosteal callus at seat of both fractures, somewhat greater on end of transplant. No thickening of periosteum over middle portion of transplant. Longitudinal section of the

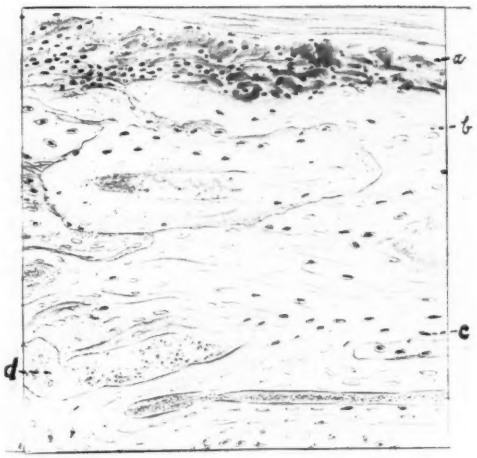

Fig. 8. 6 day Experiment No. 142. Cortex with most of its lacunæ vacant; many cells normal in appearance. a, organizing blood-clot about surface; b, vacant lacunæ; c, normal appearing cells; d, extravasated blood in haversian canals.

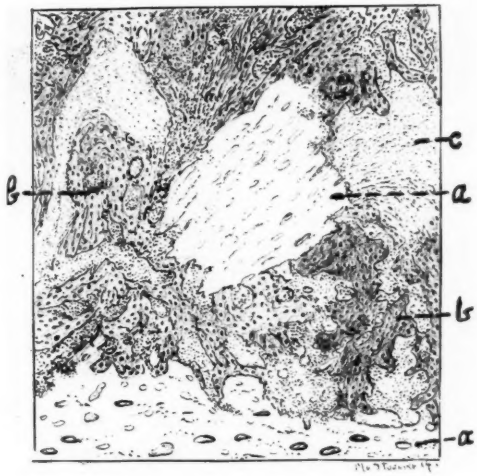

Fig. 9. 27 day Experiment No. 180. Regeneration from chips of cortex with periosteum and endosteum removed. a, pieces of old bone, lacunæ all vacant; b, new bone formed from surviving cells; c, fibrous callus.

decalcified specimen shows both intermediary calluses composed largely of fibrous tissue, but partly of organizing blood-clot between the ends of the compacta. Ends of the medullary canal of both transplant and fragments filled for a short distance with callus.

Microscopically, the periosteal calluses at the seats of fracture are fibrous except for a beginning ossification along the cortex on the ends both of fragments and of the transplant. The medullary callus filling the ends of the medullary canal at the fractures is partly ossified. The cells of the compacta of the transplant in almost one-half of its extent have either disappeared or are very much shrunken and stain poorly. The remaining cells are about normal in appearance and staining qualities. Marrow of middle of transplant normal in appearance.

26 day experiment. No. 105. Transplant two-thirds inch long.

Dog died of distemper twenty-six days after the operation; considerable emaciation. Dissection at the seat of operation shows muscles firmly adherent about the transplant. Approximation at the lower end is good. There is slight mobility, and union by a small spindle-shaped callus. Considerable lateral displacement at the lower end; free mobility and union by spindle-shaped fibrous callus. The callus at the seats of fracture is greater from the ends of the fragments than from the ends of the transplant. When the transplant and ends of the fragment are split open longitudinally the medullary canal is seen to be filled with callus for a distance of half a centimeter from the ends.

Microscopically, the intermediary callus of both fractures is fibrous, but the periosteal callus has ossified except for a thin cortical fibrocartilaginous portion. The medullary callus consists of spongy bone, and ossification of the intermediary callus is proceeding both from it and from the periosteal callus. The bone-cells of the cortex of the transplant are all dead and nearly all absorbed, leaving the lacunæ vacant. The periosteum along the transplant away from its ends is alive and on one side has formed a thin callus which has largely ossified. The medullary canal of the transplant is filled at the ends with bony callus and in its middle portion with dead marrow-cells which have been partly substituted by a pale fibrous tissue. There is no evidence of either absorption or substitution in the compact cortex of the transplant.

Here the periosteum has formed a partly ossified callus along the entire transplant on one side and at both ends. Endosteum has formed a bony medullary callus in the ends of the transplant. That this bony tissue did not come from the fragment ends by "osteoconductivity" is certain, for there is no bony bridge at either end, both intermediary calluses being fibrous. The bone-cells of the cortex are practically all dead and absorbed, but substitution by new bone has not yet begun.

51 day experiment. No. 106. Transplant four-fifths inch long.

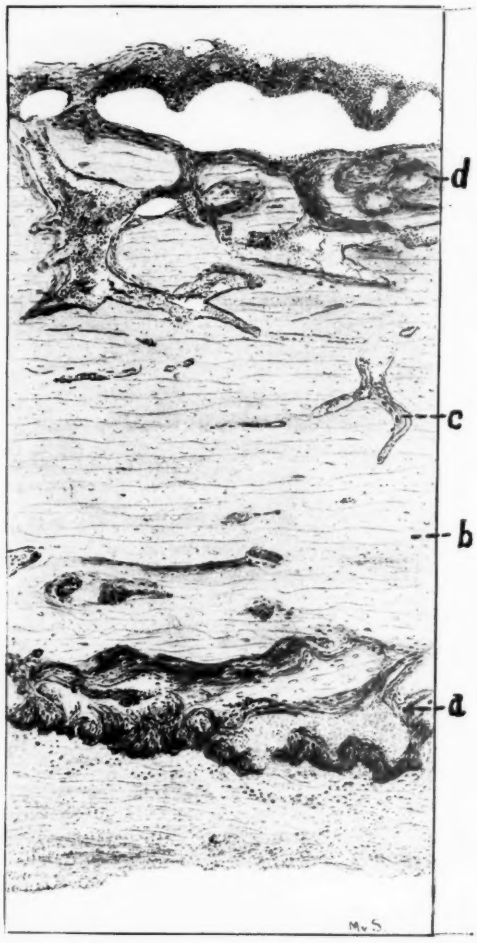

Fig. 10. 51 day Experiment No. 106. Periosteum and endosteum on. a, new bone formed from periosteum; b, dead cortex; c, revascularized haversian canal; d, new bone from endosteum.

Dissection shows the muscles adherent to the transplant as before operation. At the lower end there is perfect apposition and firm bony union with only slight thickening at the seat of fracture. There is some lateral displacement at the upper end and union is by a large spindle-shaped callus which is bony except for the intermediary callus, ossification having occurred from the ends of both the transplant and fragments. There is no enlargement of the transplant except for the callus about its ends.

Microscopically, the cells of the compacta are all dead. There is a thin layer of new bone along the surface of the transplant formed from the periosteum in most of its extent. Toward the ends it thickens and passes over into the spindle-shaped calluses. The medullary cavity at either end is filled with a bony callus which at the lower end blends with that of the end of the fragment, the intermediary callus being ossified, but at the upper end the two are separated by a fibrous intermediary callus. The medullary canal of the transplant away from the ends is filled by a pale fibrous connective tissue, all traces of marrow having disappeared. From the periosteum of the surfaces of the transplant and from the callus of the medullary canal, blood-vessels have grown into many of the old haversian canals. In many of these canals substitution has begun by absorption of the old cortex and deposition of the new bony lamellæ, so that some of the cortex has been transformed into new bone (Fig. 10).

132 day experiment. No. 107. Segment three-fourths inch long excised and reimplanted.

Dissection shows normal appearance of the ulna except for small spindle-shaped callus at the seat of the upper fracture. Seat of lower fracture cannot be detected. No mobility at either end. No appreciable thickening along the course of the transplant. Microscopical examination of longitudinal section through the transplant and through the segment shows bony union of the lower fracture by intermediary callus of dense irregular trabeculæ. Medullary canal at the seat of fracture contains a few coarse trabeculæ. At the upper fracture there is a spindle-shaped callus whose periosteal and medullary portions are completely ossified. The intermediary callus is ossified from either end except for a very narrow incomplete fibrocartilaginous zone through its middle. The cells of the compacta of the transplant have disappeared, leaving the lacunæ empty. Revascularization of the transplant has occurred with absorption of portions of the dead cortex and deposition of new bone in its place so that about one-half of the old compacta is substituted by new bone. The medullary canal of the transplant is filled partly by a pale fibrous tissue but largely by new marrow which is taking the place of the fibrous tissue (Fig. 1, Frontispiece).

350 day experiment. No. 113. Segment one inch long excised and reimplanted.

Dissection shows an apparently normal ulna. The seats of the fractures cannot be detected as there is neither periosteal nor medullary callus to be seen in the location of either. Microscopically, almost complete absorption of the old compacta has occurred with replacement by new bone. There are a few islands of old bone to be seen near the upper end of the transplant. The seat of the transplant was easily detected by the irregular course of its fibers and haversian canals as the

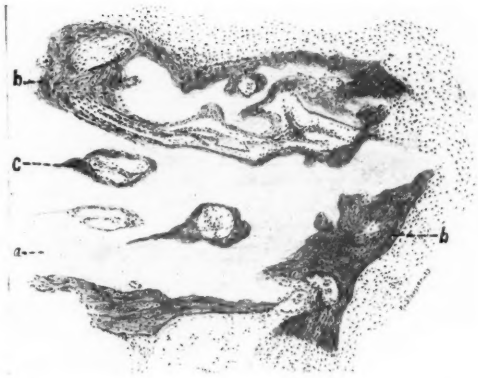

Fig. 11. 164 day Experiment No. 144 R. Transplant with periosteum removed. Dead cortex partly substituted. a, old cortex with lacunæ vacant; b, new bone; c, new bone in dilated haversian canals.

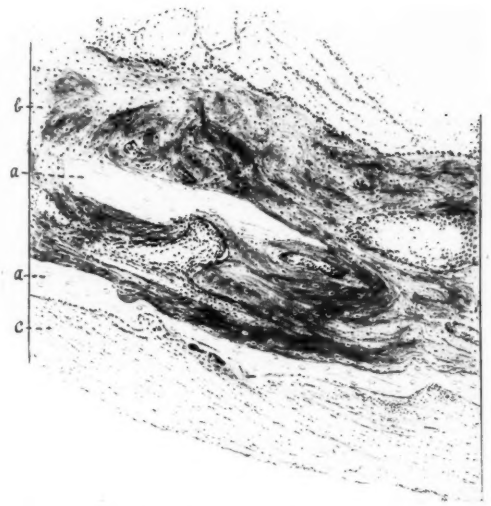

Fig. 12. 348 day Experiment No. 143 L. Transplant with periosteum removed. Dead cortex largely substituted by new bone. a, dead cortex; b, new bone; c, fibrous covering over periosteal surface.

normal arrangement into longitudinal lamellæ had not yet taken place.

b. One-half segment split longitudinally used as transplant.

Transplant with periosteum, marrow and endosteum intact but consisting of one-half of the shaft split longitudinally.

10 day experiment No. 154. Transplant three-fourths inch long.

There is a small amount of thickening of the ends of the fragments where they come in contact with the transplant. The intermediary spaces are filled in by a fibrous callus which is partly organized by an ingrowth from the ends. The transplant is surrounded in places by fibrin which is full of leucocytes and fibroblasts. There is formation of fibrous callus by proliferation of the inner layer of the periosteum along almost the entire extent of the transplant. There is a layer of fibrous callus in the exposed half of the medullary canal throughout its entire extent but most marked at the ends. About half the cells of the compacta of the transplant have been absorbed and many of those remaining stain very poorly. The ends of the fragments are filled with a small amount of new bony and fibrous callus.

33 day experiment. No. 170 L.

Dog died of distemper. The soft parts are adherent about the transplant. There is a large callus at the seat of both fractures which is undergoing ossification from the ends of the fragments. There is only a small amount of callus formed from the periosteum toward the fragment ends and almost none in the medullary cavity. There is a considerable amount of bony absorption, the numerous haversian canals being dilated and the spaces filled by fibrous tissue but no evidences of substitution. The cells of the compacta are all dead and have disappeared.

This osteoporosis without substitution by new bone and without extensive callus formation along the surface is evidence that either a mild infection occurred at the seat of the transplant or an extensive hæmatoma formed about it resulting in death of the greater portion of the periosteum and endosteum and all of the bone-cells.

64 day experiment. No. 153. Transplant three-fourths inch long.

Considerable angulation at the lower fracture. There is a rounding-off of the transplant so that it has assumed almost the form of a cylinder. There is a small bony callus at the seat of the upper fracture and a larger fibrous callus at the lower end which permits of some mobility. Microscopically, the callus uniting the upper fracture consists of rather coarse irregular bony trabeculæ. At the lower fracture where the callus is large its intermediary portion is fibrous but ossification has occurred on the end of both the transplant and fragment. A large bony callus has formed which fills out the medullary canal so that the defective half of the segment is almost restored. Along the periosteal surface there is a thin layer of new bone which becomes very much thickened as it passes over into the calluses of

the fractures. The cells of the compacta of the transplant have largely disappeared leaving the lacunæ vacant, and those which remain stain very feebly. The haversian canals are dilated, giving a coarse character to the transplant. Marked substitution of the old cortex has occurred so that one-fourth of the transplant consists of new bony lamellæ which are scattered irregularly throughout the dilated old canals. Substitution is most marked about the periphery (Fig. 2, Frontispiece).

Callus formation along the course of the transplant is very much greater from the endosteum than from the periosteum because of the functional demand on this side for restoration of the defective half.

84 day experiment. No. 156. Transplant one inch long.

Segment somewhat obliquely placed; poor approximation at the seat of both fractures. Union at either end by spindle-shaped fibrous callus. The transplant is hypertrophied, particularly along the course of the medullary canal where the callus rounds it off into a flattened cylindrical form. There is no new bone along the periosteal surface except where the calluses at the ends are ossified. The cells of the cortex of the transplant have all been absorbed, leaving the lacunæ vacant. There is revascularization of the haversian canals with considerable absorption of the old bone and ingrowth of new bone from the surfaces so that the transplant is about one-fourth substituted by new bone.

In this specimen while both intermediary calluses are fibrous the transplant contains bony callus along its entire extent and one-fourth of the cortex has undergone substitution by new bone. This conclusively disproves Dr. J. B. Murphy's contention that no new bone formation occurs from the tissues of the transplant and that it acts simply as an osteoconductive agent.

II. Transplant with its periosteum on, but with periosteum cut from the ends of the fragments for 1–1½ cm.

11 day experiment. No. 110.

Transplant is obliquely situated. There is a loose fleshy layer of tissue covering the denuded ends of the fragments and filling in the seats of the fractures. Slight thickening of the periosteum back of the denuded ends. Visible thickening of the periosteum of the transplant on the side of the angle at the lower end. Specimen decalcified and sectioned *en masse*. Microscopical examination of the ends of the fragments shows periosteum bordering on the denuded ends slightly proliferating, with ossification in its inner portion. The denuded surfaces are covered by a layer of partly organized blood-clot. The intermediary callus consists of a similar material but less highly organized. Ends of the medullary canals filled for two-thirds centimeter with fibrous medullary callus which has begun ossification along the walls of the canal. The bone-cells of the cortex for one-half to one-third centimeter from the ends are dead and many of the lacunæ are empty.

The transplant. The periosteum in the entire length of the transplant is thickened, but greatest at the ends where it forms callus for the repair of the fractures and has begun ossification along the surface of the cortex. There is a small amount of fibrous callus in the ends of the transplant but not to the same extent as is seen in the medullary canals of the fragment ends. The marrow away from the ends is practically normal in appearance. Most of the bone-cells of the cortex are either shrunken or stain very poorly. Some have entirely disappeared leaving empty lacunæ. A few scattered cells are normal in appearance. There is no evidence of absorption of the compacta.

21 day experiment. No. 133.

Dissection shows slight obliquity of the transplant. There is a spindle-shaped callus at the seat of each fracture, more marked at the upper one. Mobility at both ends. The spindle-shaped calluses have formed mostly from the ends of the transplant. The fragments show slight thickening of the periosteum at its cut margins one to one and one-half centimeters from the fractures. The surface of the ends which have been denuded of periosteum are covered by a fibrous layer which increases in thickness as the transplant is neared and takes some part in the formation of spindle-shaped calluses. Calluses are thickest on the sides of the angles. Microscopically, the periosteal thickening at the cut margin on the fragments is ossified except in its outer portion. The surface denuded of periosteum is covered by a thin layer of granulation tissue except where it passes into the spindle-shaped callus, at which point there is a small amount of ossification. In most of its extent, the denuded surface shows evidences of lacunar absorption. The cells of the compacta near the ends have died and most of them have been absorbed. The larger haversian canals, however, are filled with capillaries which are growing out from the adjacent living bone.

The transplant. The intermediary callus at both ends is fibrous. There is a periosteal callus over almost the entire extent of the surface of the transplant. It is thickest at the ends and is ossified in its inner portion. The bone-cells of the cortex and the capillaries of the haversian canals are dead and have been largely absorbed. In a few places, near the ends, there has been some absorption of cortex along the surface with revascularization of haversian canals by ingrowth from the living periosteal tissue. The ends of the medullary canal are filled for half a centimeter by a fibrous callus which has partly ossified along the surface. The rest of the medullary cavity is filled by dead marrow which is being sub-

Fig. 13. Fig. 14.

Fig. 13. Cartilaginous exostosis of upper end of the shaft of the humerus. Fig. 14. Same case as Fig. 13, showing regeneration of shaft three months after subperiosteal resection.

stituted by the ingrowth of fibrous tissue. The ends of the fragments are filled with extensive medullary callus which has ossified at the ends and ossification has begun to extend into the intermediary calluses.

40 day experiment. No. 111. Fig. 3, (Frontispiece). Transplant two-thirds inch long.

In good position. The seat of operation shows thickening of the transplant from the formation of a callus along its entire extent. There is a small spindle-shaped callus with slight mobility at the seat of each fracture. Back of the denuded surfaces of the fragment ends there is a ring of callus formed by the free margin of periosteum. The denuded surfaces are covered by a layer of fibrous tissue which leaves a slight groove between the spindle-shaped calluses at the seats of fracture and the rings of callus at the free margins of the periosteum. On the upper fragment, bony callus seems to be growing down over the denuded end. Microscopical examination of the ends of the fragments shows the ring of periosteal callus back of the denuded surfaces to consist of spongy bone in its inner portion and fibrous tissue in its outer portion. The covering over the denuded ends shows a few areas of ossification along the bony surface but in most places there is a roughening of the cortex from absorptive changes. The bone-cells of one-half centimeter of the end of the cortex are dead and most of their lacunæ are empty. A medullary callus of scattered bony trabeculæ fills the ends of the fragments for one-half centimeter. The transplant is surrounded in most of its extent by a callus, varying in thickness, which consists of spongy bone in its inner two-thirds, and ossification of the remaining portion is proceeding through a thin interrupted zone of cartilage which separates it from the outer fibrous callus. On one side at the lower end, periosteal callus is absent and a fibrous tissue covers over the surface. The cells of the compact bone have practically all been absorbed leaving the lacunar spaces empty. The capillaries of the haversian canals have disappeared but revascularization of the larger ones is occurring by ingrowth from the periphery. In a few places about the surface and along the haversian canals absorption of the dead bone has occurred and new bone has been substituted. The marrow of the medullary canal is dead in its central portion and it has been substituted by a pale-staining fibrous tissue. There are only a

few bony trabeculæ in the ends of the canal of the transplant. The intermediary calluses are fibrous but ossification has begun to extend into them from the ossified medullary calluses of the ends of the fragments. There is a cavity filled with fluid in the lower one between the ends of the cortex (Fig. 3, Frontispiece).

This specimen illustrates well the activity of the periosteum when left on a transplant and the scarcity of bony callus on the ends of the fragments where the periosteum has been cut away; also the impossibility of osteoconductivity as an explanation for the new bone on the transplant.

59 day experiment. No. 140. Dog, markedly emaciated, died of distemper.

Transplant three-fourths inch long. Slight infection of the wound with formation of a sinus which is still present. Transplant slightly oblique with no visible evidences of infection. Union at both ends by a fibrous callus. Free mobility at the upper end. Callus at the upper fracture is thick upon the end of the transplant but that portion over the fragment end and the intermediary callus is small. At the lower end there is lateral displacement so that one side of the cortex projects into the medullary cavity of the fragment. Union is by a small callus formed from the ends of both the transplant and the fragments. There is no thickening of the transplant except at the ends as described. Microscopically, both intermediary calluses are entirely fibrous. The denuded end of the upper fragment is covered by a thin fibrous layer, with some absorption along the periosteal surface on one side, and by a thin layer of new bone on the other which layer extends to within half a centimeter of the end. The denuded surface of the lower fragment is covered by a thin layer of fibrous tissue except at the end where the angle between it and the transplant is filled out by a callus which is ossified in its inner portion. The ends of the medullary canals of the fragments are partly filled by coarse bony callus. The cells of the cortex for a short distance at the ends have been destroyed.

The transplant. The callus at either end and along the surface consists of coarse, spongy bone in its inner portion which passes over into a fibrous outer layer with an intervening cartilaginous zone. The medullary canal is filled by a pale fibrous tissue except for a small amount of new bone filling either end. The cells of the compacta have all been absorbed leaving the lacunæ vacant. There has been considerable absorption with dilatation of the haversian canals. Blood-vessels are growing in from the periphery and in a few canals a small amount of new bone formation is seen.

There has been considerable delay in the process of healing in this case because of the sickly condition of the animal. There is also evidence of mild infection as shown by the fistula, the thick, coarse, bony callus covering the fragment and absorption of the transplant without substitution by new bone. There has been considerable delay in the ossification of the intermediary calluses.

61 day experiment. No. 139 R. Dog emaciated when killed.

Transplant two-thirds inch long; in good position. Union at both ends by small fibrous callus. Slight mobility at both ends. There is no appreciable thickening over the ends either of the fragments or of the transplant. Microscopical examination shows that both intermediary calluses are fibrous. The periosteal surface of both the transplant and the denuded ends of the fragments is covered by a layer of fibrous tissue. There is considerable lacunar absorption along both the surface of the transplant and the ends of the fragments and only a small amount of bony callus formation on the ends of the transplant. The medullary canal of the transplant is filled with marrow except at its ends, which are bridged over by bony callus. The cells of the compacta are all dead and have been absorbed leaving the lacunæ empty. In some places there has been dilatation of the haversian canals but in only a few has there been substitution by new bone. Along the medullary canal there is a layer of newly formed bone. The medullary canal is filled with fibrous tissue except for thin bridges of bone at either end. No marrow tissue is present. It is to be noted that the reaction here has been very sluggish, due, probably, to the emaciated condition of the animal.

119 day experiment. No. 139 R. Transplant two-thirds inch long; in good position.

The seat of the lower fracture cannot be made out. There is mobility at the upper end and union by a small fibrous callus. There is slight new bone formation along the surface of the transplant but none on the surface of the fragment ends. The bony union is by irregularly arranged dense trabeculæ. The medullary canal at the seat of the fracture is filled with coarse trabeculæ. At the upper fracture the intermediary callus is fibrous but that of the periosteal callus of the end of the transplant is bony. A bony medullary callus fills the ends both of the transplant and of the fragments.

The transplant. The cells of the compacta bone have all been absorbed leaving the lacunæ empty. About one-fourth of the compacta has been substituted by new bone which has formed in the dilated haversian canals.

II. TRANSPLANT WITH PERIOSTEUM REMOVED

1. Ends of the fragments with periosteum intact.

Fig. 15. 94 day Experiment No. 155 B. Periosteal flap which formed a pea-sized nodule attached to femur by a fibrous pedicle.

In this series there were seven experiments ranging in age from 10 to 119 days.

10 day experiment, No. 174.

Described in the chapter on the healing of fractures through a transplant.

11 day experiment. No. 172 R. Transplant one and one-fourth inches long.

Very small amount of periosteal callus on ends of the fragments at seat of fracture, but none on the transplant which is covered by a layer of granulation tissue. The intermediary calluses are partly fibrous and partly blood-clot and do not project beyond the surfaces. Split open longitudinally, the ends of the medullary canals both of the transplant and of the fragments are filled with a partly ossified medullary callus. Microscopically, both the periosteal and medullary calluses have begun ossification along their bony surfaces, the process being more marked in the medullary portions. About one-half of the bone-cells of the cortex of the transplant have disappeared and some of those remaining are shrunken and stain poorly. The capillaries of the haversian canals are dead and the blood-vessels of the larger ones stain poorly. Periosteal surface of fragment covered by a layer of largely organized blood-clot, and in places there is a slight amount of absorption of the cortex, but nowhere is there any callus formation. Marrow of the middle portion of the medullary canal is normal in appearance.

In this specimen there was slight callus formation on the ends of the fragments, and in the medullary canals of both fragments and transplant, but there was none on the periosteal surface of the transplant.

26 day experiment. No. 169 r. Transplent one and one-eighth inches long.

There is good approximation at the upper end with bony union by a medium-sized callus which has ossified in its periosteal and medullary portions. There is an intermediary callus of fibrous tissue which is undergoing ossification from the fragment end. Lower fracture shows considerable displacement of fragments. There is union by fibrous

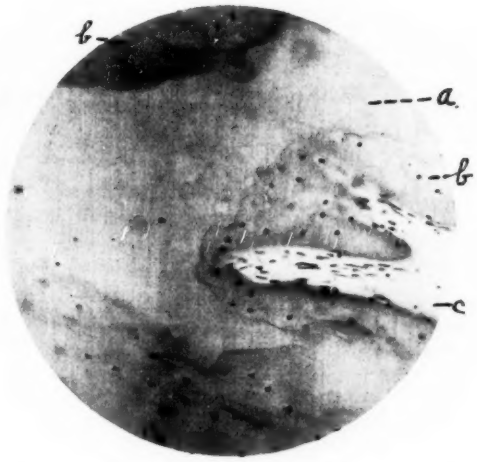

Fig. 16. Photomicrograph of 164 day Experiment, No. 144 R, showing creeping substitution of old bone by the new. a, old bone; b, new bone; c, new blood vascular canals.

callus which has partly ossified from the end of the fragment.

The transplant. On one side there is a thin layer of bony callus along almost its entire length. On the other side there is, here and there, an irregular layer of new bone. The callus on its ends is much smaller than on the ends of the fragments. The ends of the medullary cavity are filled with new bone which is not as extensive as that filling the ends of the canal of the fragments. About one-half the cells of the compacta of the transplant are dead and many of them have been absorbed. Some stain quite well and others show marked shrinkage of the nuclei. The medullary cavity away from the ends is filled by necrotic marrow.

Here again there is bony callus formation along the surface of the transplant although it is small in amount.

65 day experiment. No. 178 U. Segment one and one-fourth inches long in good position.

No callus formation about it. There is union by small fibrous callus of the upper end. There is infection and non-union at the lower end. The tip of the transplant is necrotic and sequestration is occurring. At the upper fragment union is by a fibrous intermediary callus without any periosteal callus formation whatever. The medulla of the ends of the fragments is filled by bony callus for one-half inch.

The transplant. There is no callus formation of any sort from the entire transplant. The bone-cells of the cortex are all dead and most of them have been

absorbed. The transplant is covered by a thin fibrous layer with some lacunar absorption along the surface. The lower end, which is necrotic and sequestrated, is surrounded by granulation tissue. The medullary cavity is filled throughout by loose fibrous tissue. The marrow has entirely disappeared. In this specimen there has been an unusually scanty reaction on the part of the fragments and there seems to have been complete death of the transplant. This is due both to the local infection and to the debilitated condition of the animal, which died of distemper.

87 day experiment, No. 174 L.

Is described in the chapter on healing of fractures through a transplant.

119 day experiment. No. 118.

Transplant obliquely placed. There is little callus and some mobility at the seat of both fractures. Small amount of periosteal and medullary bony callus at the ends of the fragments. Both intermediary calluses ossifying from the ends but fibrous in their middle portions. The transplant is covered by a layer of fibrous tissue and shows roughening and absorptive changes along its surface except at the ends, where there is some bony callus filling out the angles. The medullary canal is filled at the ends with a small amount of bony callus and with fibrous tissue in the rest of its extent. The bone-cells of the compacta are all dead and absorbed leaving the lacunæ vacant. The larger haversian canals have been revascularized and there has been some substitution of the dead bone by new, particularly along the endosteal side toward the ends.

2. Ends of the fragments with periosteum removed.

6 day experiment. No. 142. Transplant three-fourths inch long.

Dissection shows fragment in good position. Blood-clot covers the denuded fragment ends and the transplant and fills in the intermediary spaces of the fractures. There is no thickening of the periosteum bordering on the denuded ends of the fragments. Microscopically, the lower fragment has a fibrous clot covering the surface of the denuded end which is partly organized by the ingrowth of granulations. Periosteum bordering on the denuded end shows slight thickening in its inner portion. The end of the medullary canal is filled for a distance of one centimeter by fibrous callus which is just beginning ossification along the surface. Upper fragment. The surface freed of periosteum is covered by an organizing blood-clot except in a few places on one side where there are islands of fibrous callus which have evidently formed from portions of periosteum which were not removed. The cells of the ends of the fragments stain poorly and many of them have been absorbed. The transplant is surrounded by a layer of organizing blood-clot. The medullary cavity is filled with blood in almost its entire extent. There is no fibrous callus in the ends of the cavity. There are two or three islands of callus along the periosteal surface which are evidently due to the proliferation of small periosteal rests. Most of the cells of the compacta of the transplant either show evidences of necrosis or have been absorbed. Other cells stain quite normal. There is no evidence of absorption or new bone formation within the substance of the compacta (Fig. 8).

10 day experiment. No. 120. Transplant three-fourths inch long.

Dog died ten days after the operation but there is no evidence of infection. The muscles were adherent to the transplant by loose granulation tissue. There was little blood in the vicinity. The segment is slightly obliquely placed. The surfaces of the fragment ends and of the transplant are covered by a layer of fibrous tissue and the intermediary spaces of the fractures are filled in by a granulating blood-clot. The transplant is easily dislodged from its position.

Upper fragment. The periosteum bordering on the denuded end is slightly thickened with ossification along the cortical surface. The denuded surface is covered by a layer of granulation tissue without any evidence of ossification. Lower fragment. The periosteum has formed quite an extensive ridge of callus back of the denuded end, which is covered by a partly organized blood-clot. The callus at the cut end of the periosteum is bulging forward on the surface of the denuded end.

The transplant. The transplant shows no periosteal callus along its surface. There is a small amount of fibrous callus filling the ends of its medullary canal. The cells of the compacta stain poorly, about a third of them being absorbed. The marrow filling the medullary cavity away from the ends is almost normal in appearance.

28 day experiment. No. 141. Transplant one-half inch long.

Somewhat obliquely placed. There is a slight spindle-shaped callus at the seat of both fractures, more marked at the upper one where the displacement is greater. The denuded ends and the surface of the transplant are covered by a layer of fibrous granulation tissue. There is slight thickening about the cut ends of the periosteum of the fragments. Mobility of both fractures. Microscopically, the callus formed at the cut ends of the periosteum has ossified in its inner portion and on the ends of the transplant and of the fragments there is slight ossification of the spindle-shaped peripheral calluses at the seats of fracture. The fibrous layer covering the transplant shows no ossification except at the ends specified. The intermediary callus of both fractures is fibrous. There is a largely ossified medullary callus filling the ends of both the fragments and the transplant, but much greater in amount in the ends of the fragments.

The marrow-cells of the middle of the transplant are dead and there is a small amount of substitution by fibrous tissue. The bone-cells have nearly all disappeared and those which remain have shrunken nuclei and stain very poorly.

38 day experiment. No. 121. Transplant one-half inch long.

Considerable angulation at the lower fracture. Dissection shows soft parts firmly adherent about the transplant with small spindle-shaped calluses at the seats of fractures, more marked at the upper. The intermediary calluses are fibrous. Free mobility of both fractures. Periosteum back of the denuded ends has formed a ring of bony callus on both fragments, and there is a covering of fibrous tissue of moderate thickness about the transplant. Microscopically, the denuded ends of the bones are covered by a thin layer of fibrous tissue in which there is practically no ossification. Toward the ends of the transplant where the callus is thickest on the side of the angles there is a small amount of ossification along the cortical surface of the bone. The covering of the transplant elsewhere consists of fibrous tissue. Ends of the fragments filled by a bony callus for two-thirds centimeter. The ends of the medullary canal of the transplant are filled by a fibrous callus which is partly ossified along the surface. The marrow of the middle portion is necrotic. The cells of the compact bony cortex have largely disappeared leaving the lacunæ vacant. Capillaries of the haversian canals are also dead and the canals are largely empty. About the periphery revascularization is occurring by an ingrowth of capillaries from the fibrous covering. There is a small amount of absorption about the surface and ends of the transplant.

42 day experiment. No. 122. Transplant three-fifths inch long.

There was infection at the seat of operation and the formation of a sinus which persisted up to the time the animal was killed. Dissection shows a granulating wound at the seat of operation. The transplant is surrounded by a mass of granulation tissue except at the lower end laterally at the termination of the sinus where its surface is entirely bare. There is a marked bulb-shaped callus on the ends of both fragments back of the denuded portion. There is death of the denuded ends and sequestration is occurring. The intermediary spaces of the fractures are filled by a serous exudate. The granulation tissue which surrounds the fragment has also grown into and completely filled the medullary cavity. There is marked roughening of the surface and absorption of the transplant so that more than half of it has disappeared; also marked absorption along the surface of the dead fragment ends. The ends of the fragments are filled for one-half to one centimeter with a bony medullary callus. Microscopically, the entire unabsorbed portion of the transplant is dead and there is absolutely no bone formation along any portion of its surface.

Infection resulted in the complete failure of this experiment and the rapidity with which absorption is occurring makes the transplant analogous to a sequestrum in a case of osteomyelitis.

164 day experiment. No. 144 R.

Transplant three-fourths inch long; in good position. Firm bony union at the lower fracture with only slight callus persisting. At the upper end there is fibrous union, a large callus, and considerable mobility of the fragments. There is no thickening along the course of the transplant except at the ends. Microscopically, the lower fracture is united by a callus, consisting of irregular bony trabeculæ, which projects only slightly beyond the surface and fills to some extent the medullary cavity at its seat. The surfaces of the denuded ends and the transplant are covered by a fibrous tissue which is indistinguishable from the periosteum with which it is continuous. The large spindle-shaped callus at the upper fracture is fibrous in its intermediary portion but is ossified on the surfaces of the ends of the bones slightly more marked on the end of the fragment than the transplant. The ends of the medullary canals bordering on the intermediary callus are bridged over by a thin layer of bone. Ossification of the intermediary callus is proceeding from the ends of both transplant and fragment. The medullary cavity of the transplant in its upper portion is filled by pale-staining, sparsely nucleated fibrous tissue, but toward the lower end a considerable amount of new bone-marrow has been formed. The old compacta of the transplant is entirely devoid of cells. There has been marked absorption of the dead bone and dilatation of the haversian canals with new bone formation so that about one-third of the transplant has undergone substitution. This substitution is equally marked on the periosteal and medullary sides (Figs. 11 and 16).

Despite the fact that periosteum was removed from the ends of the fragment and from the transplant, substitution of the dead cortex of the transplant is taking place and bony union of the fractures is occurring; however, it has been much slower in occurring than in the experiment of corresponding age where the periosteum was intact.

199 day experiment. No. 144 L. Transplant four-fifths inch long.

In good position. Muscles and tendons adherent very much as before the operation. At the lower fracture there is firm bony union and except for a slight irregularity on one side its location could not be distinguished. At the upper fracture there is fibrous union by a medium-sized spindle-shaped

callus. There is no thickening along the course of the transplant away from its ends. The denuded surfaces of the fragments and of the transplant are covered by fibrous tissue which is firmly adherent and resembles periosteum. Microscopically, the lower fracture is united by a callus of irregular dense bony trabeculæ. The medullary canal at its seat is almost entirely restored, there being only a few coarse bony trabeculæ left. The spindle-shaped callus at the upper fracture has ossified on the ends of the bones but the middle zone of the intermediary callus consists of fibrocartilaginous tissue which is undergoing ossification from either end. Small amount of bone in the ends of the medullary cavity bordering on the intermediary callus. The transplant shows no thickening along its surface. The cells of the cortex of the transplant have all disappeared and more than two-thirds of the old compacta has been absorbed and substituted by new bone which consists of irregularly arranged trabeculæ and lamellæ. The medullary cavity is filled by a pale fibrous tissue in which there is a small amount of new bone marrow, here and there, about the periphery (Fig. 4, Frontispiece).

293 day experiment. No. 143 R. Transplant three-fourths inch long.

Approximation good at both ends. There is a small spindle-shaped callus at the seat of both fractures, slightly larger at the lower one. There is firm bony union at the upper end but fibrous union with slight infection at the lower. There is a small amount of granulation tissue with a fistula at the seat of the lower fracture. The denuded ends and the transplant are covered by a fibrous layer resembling periosteum. Microscopically, the callus at the upper fragment consists of bone except for a very narrow incomplete layer of fibrocartilaginous tissue in the intermediary zone. The callus uniting the lower fracture is osseous on the surface both of the end of the transplant and of the fragment. There is a very narrow zone of intermediary callus which is still fibrous. The medullary canal is filled for half a centimeter on either side with bony trabeculæ.

The transplant. Cells of the old compacta are dead and it is three-fourths substituted by new bone. The substitution in most of its extent is more marked in the inner portion near the medullary canal. The new bone has been deposited in irregular lamellæ along the course of the haversian canals as absorption of the old bone has taken place. The medullary canal away from the ends is filled by a mixture of fibrous tissue and new bone-marrow which contains some fat.

Despite the fact that bony union at the seat of both fractures is incomplete, three-fourths of the compacta of the transplant has been substituted. The bone-marrow is being regenerated in the medullary canal of the transplant, gradually taking the place of the fibrous tissue which filled the canal in the earlier experiments.

348 day experiment. No. 143 L. Transplant three-fifths inch long.

Soft parts adherent to the ulna as before the operation. There is complete bony union at the upper fracture and it is impossible to distinguish its location. At the lower fracture there is slight lateral displacement and an abrupt small spindle-shaped callus which permits of slight mobility. There is no enlargement along the course of the transplant except for this slight callus at the lower end and it is covered by a layer of fibrous tissue which is continuous with and similar to the periosteum. Microscopically, the bony callus uniting the upper fracture consists of dense and irregular trabeculæ. The lumen of the medullary canal at its seat is practically restored to normal. At the lower fracture the callus is ossified on the ends of both transplant and fragment, but the middle zone of the intermediary callus is fibrocartilaginous. The covering of the transplant consists of fibrous tissue. The old cortex in regions is entirely substituted by newly formed, irregularly arranged bony trabeculæ. In other regions there is a small amount of the old cortex with vacant lacunæ still remaining. The medullary canal is filled with normal marrow. (Fig. 12.)

In this specimen the transplant is very largely substituted by new bone which instead of having its fibers arranged parallel with the long axis of the bone consists of irregularly arranged trabeculæ. Regeneration of the bone-marrow is complete. However, both substitution and the healing of its fractures are slower than in the 350 day experiment where periosteum was left on the transplant.

From these experiments it is seen that when periosteum is removed from the transplant, the end of the fragment, or both, the peripheral callus at the seats of fracture is much smaller than when periosteum is left on and union of the fractures is thereby delayed. However, some peripheral callus forms not only from the growing out of the medullary callus, but also from the bone-cells along the cortex which survive and proliferate. Transformation of the dead cortex into new bone by absorption and substitution, and regeneration of the bone-marrow, is occurring from the surviving cells of the transplant. This proves conclusively that a transplant devoid of periosteum may be successfully used for the repair

of a bony defect although the restoration is slower than when the periosteum is left on.

III. TRANSPLANT OF CORTEX ONLY, WITH BOTH PERIOSTEUM AND ENDOSTEUM REMOVED

1. Transplant in one piece.

21 day experiment. No. 159.

A piece of the crest of the tibia one inch long was excised, its periosteum and endosteum removed, and the cortex of both sides whittled off so that the transplant consisted exclusively of compact bone giving it the appearance of an ivory peg. Transplant obliquely placed. Approximation fair at either end. There is a moderate-sized callus and some mobility at the seat of either fracture. Callus is much more marked on the ends of the fragments than on the ends of the transplant. There is a thin fibrous layer covering over the transplant. Microscopically, the periosteal and endosteal portions of the callus at the seats of the fractures are entirely ossified on the ends of the fragments but the intermediary callus consists of fibrous tissue which is undergoing ossification by an extension inward of the process from them. The smaller calluses on the ends of the transplant are largely fibrous but along the cortical surface at the ends there is quite extensive ossification. The transplant is somewhat porous along the medullary side. The cells of the compacta have all disappeared leaving the lacunæ vacant but along the medullary side and in these pores some of the cells have lived and there are lamellæ of new bone. Revascularization of some of the haversian canals has occurred. Along the periosteal side there is no new bone formation except in the calluses at the ends but the surface is rough from the occurrence of lacunar absorption.

Despite the fact that the periosteum and endosteum were whittled away from this transplant a small amount of callus formation occurred from its ends which has undergone some ossification along the bony surface and some new bone formation has occurred along the medullary side and in the porous spaces. That this new bone formed from bone-cells which lived is a certainty, for the intermediary calluses are entirely fibrous, and consequently, osteoconductivity as an explanation is out of the question. The few cells which lived about the ends of the transplant have undergone extensive proliferation because of the functional demand in this location for repair of the fractures.

46 day experiment. No. 176.

The transplant, slightly obliquely placed, consists of a splinter one inch long, taken from the crest of the tibia with its periosteal and endosteal surfaces whittled off. The splinter is somewhat flattened and a little shorter than the space to be filled in. At autopsy the soft parts are adherent about the transplant, which is found to be considerably smaller in diameter than the fragments. There is a small fibrous callus uniting both fractures. The transplant is apparently not enlarged. Microscopically, the callus at both ends is fibrous in its intermediary portions but has ossified both from the ends of the fragment and from the ends of the transplant, although much less markedly from the latter. The callus formation is more marked on the sides of the angles and ossification of the callus on the end of the transplant has occurred only on those sides. The cells of the bony transplant have practically all been absorbed. There are some large canals and pores along the medullary side into which blood-vessels have grown and there is slight new bone formation along their walls. There is absorption along the periosteal surface where there is no callus formation except at the ends (Fig. 5, Frontispiece).

Here, despite the fact that both periosteum and endosteum are removed, there is a small amount of new bone formation both in the calluses at the ends and in the larger pores along the medullary side. A very small amount of substitution has occurred about these pores.

75 day experiment. No. 177.

The transplant consists of a portion of compact bone from the crest of the tibia with its periosteal and endosteal surfaces whittled off. Dissection shows no enlargement along the course of the transplant. There is fibrous union at both ends. Considerable ossification of the calluses uniting the fractures has occurred from the ends of the fragments; only a very small amount on the sides of the slight angulation from the ends of the transplant. The cells in the remaining compacta of the transplant have all been absorbed. There has been a small amount of revascularization and dilatation of the haversian canals and along the medullary surface a small amount of new bone formation. Along most of the periosteal and some of the endosteal sides there has been some lacunar absorption.

Here, too, a small amount of new bone formation has occurred from cells about the periphery of the transplant which have lived, and a suggestion of substitution of the transplant is present. The importance of functional demand in hypertrophy of the bone is shown by the more extensive bone formation in the calluses where there is demand for union of the fractures.

In this type of experiment where so very few of the transplanted cells remain alive

they have a gigantic task thrown upon them in the regeneration and transformation of the transplant. In fact, in the last experiment, absorption in some portions by the surrounding fibrous tissue has exceeded in amount the substitution by these surviving cells, which had occurred in others, so that the transplant is slightly smaller than when inserted. It is probable that after several months when bony union of the fractures is complete the much more abundant bony callus of the fragments would grow into the transplant and take part in its transformation. This is what one would expect to happen in the case of a medullary peg used for ununited fracture where the transplant is everywhere surrounded by a callus derived from the medullary contents.

2. Transplant cut into several small fragments.

After removal of periosteum and endosteum and scraping the surfaces well, the remaining portion was cut into twelve or fifteen small fragments which were placed within the defect. There were three experiments, 8, 27, and 55 days old respectively.

8 day experiment. No. 181.

Dog died from distemper. Dissection showed no infection of the wound. The small fragments were embedded in a blood-clot which was partly organized by an ingrowth of fibroblasts from the surrounding soft parts. The entire region was hardened, decalcified, and sectioned *en masse*. Microscopically, the structure surrounding and between the fragments consists of a network of fibrin which in most places has been invaded by capillaries and fibroblasts and particularly about the periphery has been entirely replaced by a loose connective tissue.

The bone-cells in some of the pieces stain well, only a few having disappeared, while in others most of them either have disappeared or stain poorly. As a rule, there is no callus surrounding the fragments but in a few places islands are present which have undergone partial ossification along the fragment surfaces. The ends of the shaft show a moderate amount of periosteal and medullary callus formation which has undergone ossification along the bony surfaces, but none of this callus has grown out and surrounded any of the fragments. The bone-cells in the end of the cortex for one-third to one-half centimeter are either dead or stain poorly as a result of the disturbance to their circulation.

27 day experiment. No. 180. Young dog.

Dissection shows union of the two ends by a callus which is slightly greater in diameter than the shaft and envelops all of the splinters except the ends of two which protrude from the surface. The callus is partly ossified and permits some mobility. The specimen was decalcified and sectioned *en masse*. Microscopical examination shows a thick layer of callus, surrounding some of the pieces which is ossified on the surface of the bone but fibrous in its outer portions (Fig. 9). The bone-cells of these fragments are mostly dead but some appear alive and stain well. Two of the smaller fragments are surrounded by fibrous callus without a trace of ossification on their surfaces. Their cells are practically all destroyed and there is considerable roughening from lacunar absorption.

The ends of the shaft contain an abundance of periosteal and medullary callus which is ossified except in its more distal portions. The bone-cells of the very ends of the cortex have disappeared. The bony callus which surrounds each fragment and covers the ends of the shaft is, as a rule, separated from that of the other fragments by interstices of fibrous and cartilaginous callus, so that each fragment has been a center from which callus formation and ossification has proceeded. Hence we must conclude that some cells in most of the fragments lived and gave rise to callus formation despite the fact that the great bulk of the bone-cells have undergone necrosis.

55 day experiment. No. 182.

Dissection shows a moderate-sized callus surrounding the fragments, uniting the ends of the shaft and permitting very slight mobility. The callus from the upper end of the shaft is more marked than that from the lower. Some of the pieces of bone are dead and very largely absorbed, but the majority of them have a covering of bony callus which in places connects with that of the other pieces and with the ends; while in others it is separated from the rest by intervening fibrous or cartilaginous callus. Practically all of the cells in the pieces have disappeared, leaving the lacunæ vacant, and substitution of the dead cortex by absorption and the deposition of new bone in its dilated canals is well under way.

These experiments show that when small fragments of bone devoid of both periosteum and endosteum are used to bridge over a bony defect some of their cells remain alive, proliferate, and form callus which plays an important part in the restoration of the continuity of the shaft. However, the old cortex of the fragment which dies is gradually absorbed and substituted by new bone. These small fragments show more osteogenesis than the single pegs of cortex which were used in the first series of experiments which is due to the fact that a greater number of cells have access to nutrition and because of the macer-

ated and weakened condition of the transplant they are more stimulated to hypertrophic and reparative changes.

IV. DEFECT FILLED IN BY PERIOSTEUM

A. Subperiosteal resection.

1. There were three specimens, 11, 54, and 116 days old respectively, in which the ulna in full grown dogs was resected subperiosteally. In all three the defect was bridged over by fibrous tissue and in none was there any evidence of regeneration of the shaft from the remaining periosteum. The ends of the fragments were rounded off. Microscopically the bridge consisted of fibrous tissue and the medullary cavity was closed over by new bone very much as one sees in an amputation stump.

Subperiosteal resection of the shaft where there is only one bone in that portion of the extremity is followed by different results.

In a 10-year old child where, because of a cartilaginous exostosis, the upper four inches of the shaft of the humerus was resected by Dr. Culper and the greater portion of the periosteum left behind, in 3 months it regenerated the shaft in its entire length as shown by the X-ray photographs in Figs. 13 and 14.

In a young dog operated on in the same way a similar but less complete regeneration consisting of spongy bone had occurred when the animal was killed at the end of sixty days. There was considerable shortening because no extension could be kept up on the extremity.

In a similar experiment of the same age in an old dog where the periosteum was very thin there was only a small spicule of new bone formed in the defect at the upper end. This difference with age is explained by the fact that the periosteum in the young is much thicker and possesses a marked inner or cambium layer with marked regenerative powers which is almost entirely absent in the old. The difference between the results in the ulnar and humeral resections is due largely to the difference in function. The humerus has the entire support of the arm, while the radius is the chief support and weight bearer of the forearm, so that in case of subperiosteal resections of ulna and humerus there is nothing like the functional demand made upon the former as upon the latter.

2. Subperiosteal resection with reimplantation of excised cylinder of the shaft.

8 day experiment. No. 183.

In a young dog with the epiphyseal lines persisting the lower half of the shaft of the radius was resected subperiosteally through a slit in one side and reimplanted, a small amount of the metaphysis on one side remaining with the epiphysis. Periosteum stitched about the reimplanted piece. Dog died eight days later. Dissection showed upper end protruding through the slit in the periosteum with considerable over-riding of fragments. Lower end in good position. Except at the upper end, the reimplanted shaft is surrounded by periosteum very much as if it had not been operated upon. There is no mobility at the lower end. Specimen was decalcified and sectioned *en masse*. Examination of a longitudinal section shows marked fibrous callus formation from the periosteum about the reimplanted shaft but separated from it in most places by a layer of organizing blood-clot. No evidence of ossification in the callus formed from the periosteum. The approximation of the epiphysis with the metaphysis is perfect and there is union by an almost completely ossified callus. No evidence of new bone formation from the surface of the transplant. The medullary cavity of the metaphysis is full of fibrous and spongy bony callus. Separation of the lower end was in the juxta-epiphyseal region and the epiphyseal line has been unchanged by the process. About one-half of the cells of the compacta of the reimplanted portion have disappeared, and the nuclei of many of those remaining stain poorly.

In this specimen where the shaft was reimplanted and function thereby thrown upon the ulna, the periosteum has formed a fibrous callus surrounding the lower half of the reimplanted bone.

21 day experiment. No. 184 R. Young dog; epiphyseal lines open.

Lower half of the shaft of the radius excised subperiosteally and reimplanted after boiling. The ends of the bone at the lower fracture are in good position. There is considerable lateral displacement at the upper one with the end of the reimplanted segment protruding through the periosteal sheath with mild infection and destruction of a part of the periosteum. There is thickening of the periosteal cuff surrounding the lower two-thirds of the reimplanted bone. Longitudinal section shows that the lower fracture passed through the metaphysis about half a centimeter above the epiphyseal line. The fracture is united by a fibrous callus which is partly ossified from the epiphyseal end. Ossification of the callus formed from the periosteum and surrounding the lower two-thirds of the reimplanted shaft has begun at the lower end and extends upward in the shape of a cuff for a distance of two centimeters. It is separated from the surface of the shaft by a layer of fibrous callus above, but below comes in direct contact with the boiled bone. The cells of the dead cortex are nearly all absorbed. The medullary cavity is filled with dead cells and extravasated blood except at the ends where fibrous tissue has grown in.

In this specimen the periosteum surrounding a piece of dead bone which partly supported the extremity was stimulated to the formation of a partly ossified callus about it

and bridging over the defect except above where periosteum had been destroyed.

33 day experiment. No. 184 L.

One inch of the shaft of the radius resected subperiosteally and reimplanted with periosteum imperfectly sutured over it. The surface of the cortex was not scraped so that any periosteal rests that were not removed were reimplanted. Dissection shows a spindle-shaped callus at the seat of both fractures and thickening along the course of the reimplanted portion. Longitudinal section of the entire area shows the periosteal callus on one side to be ossified on the ends of the fragments over the seats of fracture and extending over either end of the transplant for a distance of one-third its length leaving the middle third fibrous. These projections of bony callus are separated from the surface of the transplant by fibrous callus and except for a small island toward the upper end there is no ossification along the surface of the transplant. The other side along which the periosteum was split presents an entirely different picture. The transplant is slightly displaced toward that side. On the ends of the fragments and along the entire length of the transplant there is a layer of bony callus, but at the seat of either fracture the intermediary callus on this side and between the two ends of the bones is fibrocartilaginous. The cells of the compacta of the transplant have practically all disappeared and the haversian canals are partly revascularized. There is some absorption of dead cortex about the surface but no substitution of dead bone by new has occurred. The medullary canal away from the ends is filled with a necrotic marrow which is partly substituted by fibrous tissue. The ends contain a small amount of bony callus. On one side of the transplant the layer of callus was undoubtedly formed from the periosteum left behind because its bony portion is separated from the cortex by a fibrous layer. On the other side the new bone is in contact with the surface of the cortex and is separated from that of the ends of the fragments by a fibrous intermediary callus at either end, so that it seems to have originated from the transplant.

From this set of experiments it may be concluded that when bone is resected subperiosteally and reimplanted into the defect, even after boiling, its presence lends some support to the limb and acts as a stimulus to the periosteal sheath to proliferate and form a cylinder of callus about it. Ossification of this callus proceeds from the ossified callus of the ends of the fragments and gradually extends inward from either end toward the middle; for ossification of a fibrous callus, i. e., the transformation of fibrous into bony cells, always begins on the surface of the living bone, and never as separate islands in remote portions. Just why this is, is not known, but it is probable that the bone-cells exert some chemical or physicochemic influence upon their neighboring fibrous cells that causes them to take on the properties of ossification. That the property of ossification may at times originate in the fibrous cells, themselves, away from bone, is shown by the fact that periosteum free in the soft parts will occasionally give rise to new bone formation, and by ossification in muscles, etc., following trauma. This will be discussed more fully in connection with transplantations into the soft parts.

B. Reimplantation of the periosteum removed from an excised segment.

In four experiments, 10, 41, 70, and 139 days old respectively, the periosteum was removed from the excised segment, rolled up and reimplanted into the defect. Dissection in each case showed the ends of the fragments covered over by fibrous tissue and usually a fibrous band bridging over the defect without any new bone formation on the part of the reimplanted periosteum. In the older sepcimens the ends of the fragments were rounded off and the medullary canal bridged over by new bone as in an amputation stump.

Bone weakened by injury or disease receives a stimulus to proliferate from the demand made upon it by the other parts of the extremity for support. The periosteum is the important regenerative tissue and derives its impulse to proliferate *from the bone* to which it is either attached or intimately related as in Group 2 of Experiment IV–B. When periosteum is completely detached and remote from its bone, as in this case, there is no stimulus for proliferation thrown upon it and consequently, as a rule, no new bone formation.

V. BOILED BONE TRANSPLANTED INTO A BONY DEFECT

Specimens of bone averaging one inch in length were excised from the ulna, boiled for five minutes, and reimplanted into the defect. There were five experiments ranging in age from 10 to 200 days.

10 day experiment. No. 170 R.

Transplant surrounded by, and medullary cavity and intermediary spaces filled in with, an organizing blood-clot. No apparent thickening of the periosteum of the ends of the fragments. Microscopically,

there is a small amount of fibrous callus with beginning ossification in the ends of the canals of the fragments. Cells of the compacta of the transplant are mostly all well preserved (by the heat fixation) but many of them about the surface have been absorbed.

20 day experiment. No. 126. Transplant three-fourths inch long.

The dog, sick with distemper, was killed at the end of twenty days. There were no adhesions of the muscles about the transplant. It was encapsulated by a thin layer of fibrous tissue. There was no callus formation at the seats of the fractures, neither about the ends of the transplant nor at the ends of the fragments. Intermediary spaces are filled in by fibrous tissue; free mobility at seat of each fracture. Microscopical examination of the ends of the transplant shows that there is only a very small amount of fibrous periosteal callus, and a partly ossified callus filling the end of the medullary canal. The cells of the compacta of the transplant were nearly all absorbed. There is a small amount of roughening from lacunar absorption along the periosteal surface and ends. The medullary spaces are partly filled by fibrous tissue.

70 day experiment. No. 125.

Transplant one inch long in good position. Muscles adherent about it. The transplant is surrounded by a thin fibrous capsule. At the seats of the fractures there is only a very small amount of callus formation from the ends of the fragments. Loose fibrous union at either end. The segment itself is slightly decreased in size from lacunar absorption along the surface. Fibrous tissue fills the marrow spaces. A very small amount of bony callus bridges over the ends of the medullary canals of the fragments.

75 day experiment. No. 123.

Shows practically the same condition as the 70-day experiment with the small amount of reaction on the part of the fragment ends.

200 day experiment. No. 127.

Transplant three-fourths inch long, in good position. Muscles adherent about it. Transplant surrounded by a layer of fibrous tissue. Fibrous union and free mobility at either end. A very small amount of bony and medullary callus has formed from the ends of the fragments. No ossification of either fibrous intermediary callus except for a small amount proceeding from the small endosteal and periosteal calluses of the fragment ends. The cells of the compacta of the transplant have all been absorbed leaving the lacunæ vacant. There is diminution in size of the transplant with some roughening of its cortical surface from lacunar absorption. Its medullary canal is filled by fibrous tissue except for a few places where a thin layer of new bone has formed along the surface of its wall. This is a small amount of heteroplastic bone formed from the surrounding fibrous tissue similar to that about the older specimens of boiled bone in the soft parts.

It is to be noted that there is very little reaction on the part of the ends of the living fragments which is in marked contrast to that which occurs when a live transplant is used. The dead bone does not stimulate osteogenesis to the same degree as a live transplant, consequently bony union between fragments and transplant had not occurred, much less had there been any substitution by an ingrowth of new bone from the ends. In the oldest specimen some heteroplastic bone has formed on the ends of the transplant from the surrounding fibrous tissue in response to the demand for union with the ends of the shaft.

VI. THE HEALING OF A FRACTURE THROUGH THE MIDDLE OF A TRANSPLANT

In five experiments a long transplant was fractured in the middle and the ends well approximated and slightly impacted before reimplantation. In three specimens the periosteum was removed and in two others it was left on.

1. Fracture through the transplant with periosteum intact.

25 day experiment, No. 175.

Transplant two inches long. There was mild infection of the wound with a discharging sinus. Dissection shows infection at the seat of the upper fracture with death of the periosteum over one centimeter of the end of the transplant leaving the surface bare and the end of the bone a sequestrum. There is non-union between it and the upper fragment whose end is covered by a moderate-sized, partly ossified callus. At the lower fracture there is firm union by a small bony callus. At the seat of fracture in the transplant there is considerable angulation and bony union by a large periosteal callus which is thickest on the side of the angle. This callus diminishes away from the fracture and entirely disappears on the lower portion before the lower fracture is reached. On the upper portion it extends up to the necrotic end which borders on a cavity to which the fistula leads. Longitudinal section shows evidence of slight infection along the entire transplant. The layer of new bone formed from the periosteum surrounding the transplant is very thick and spongy resembling in extent and structure the involucrum seen in osteomyelitis. The space between the ends of the fracture through the middle is filled by infectious granulation tissue and leucocytes, and there is only a small amount of callus formed in the ends of the medullary canal at

this point. The medullary cavity away from the ends is filled partly by dead marrow and partly by an exudate with only a small amount of fibrous tissue in the lower piece. Union at the lower fracture is by a very small callus which is bony except in its intermediary portion on one side where it is still fibrous. The entire cortex of the transplant is dead and its cells have all been absorbed. There has been considerable absorption of bone along the surface and dilatation of haversian canals by ingrowing blood-vessels from the spongy bony periosteal involucrum. Substitution of the dead bone along these dilated canals is well under way.

The influence of infection upon this specimen is marked. It has led to non-union at one end by causing death of the tissues, sequestration of two-thirds centimeter of the end of the transplant, and the formation of an involucrum by that portion of its periosteum which survived. It has also produced marked absorption of the dead cortex. The fracture in the transplant healed by a much larger bony periosteal callus than that about either end, showing conclusively that the origin of this callus is from the transplanted periosteum and that osteoconductivity played no part in its formation. The entire cortex of the transplant is dead but it has behaved differently in different portions. At one end, where infection was severe, it has undergone sequestration, while in the rest of its extent absorption and substitution by new bone has begun. Hence, sequestration and necrosis of bone are not synonymous since dead bone may be invaded and substituted by new bone instead of being separated and cast off.

35 day experiment. No. 172 L.

Dog died of distemper, very markedly emaciated, so that healing powers were considerably diminished. Dissection shows a large spindle-shaped callus at the seat of the upper fracture, much greater from the end of the fragment than from the transplant, a small callus at the lower end, considerable thickening along the entire course of the transplant, and a small spindle-shaped callus at the seat of fracture through the middle. All three fractures are slightly movable. There is ossification of the inner three-fourths of the large periosteal callus at the seat of the upper fracture and of all of the medullary callus filling the ends of both the transplant and fragment. The intermediary space is bridged over by a band of fibrous tissue in its peripheral portion connecting the two periosteal calluses, but the space between the ends of the cortex is occupied by a cavity filled with serohæmorrhagic exudate. At the lower fracture there is likewise ossification of the medullary callus, of the greater portion of the periosteal callus, and of the intermediary callus except for an incomplete narrow disc in its middle portion. The callus along the course of the transplant is ossified in its inner portion and fibrous in its outer. At the seat of the fracture in the transplant there is a slight spindle-shaped periosteal callus with ossification on the ends of the fragments but with a fibrous intermediary callus. There is no medullary callus at the seat of the fracture and the medullary canal of the entire transplant is filled with dead marrow except toward the ends which are filled with loose fibrous tissue. The lacunæ of the cortex are nearly all empty from death and absorption of the bone-cells. Capillaries are growing into the large spaces and haversian canals. No substitution by new bone is to be seen.

45 day experiment. No. 161 R. Transplant two inches long.

Dissection shows slight lateral displacement at both the upper and lower fractures, more marked at the upper. There is a medium-sized callus with free mobility at either end. At the fracture in the transplant there is very slight angulation, a very small callus, and firm bony union. Aside from the thickening at the seats of fracture there is no enlargement along the course of the transplant. Longitudinal section shows ossification of the periosteal and medullary portions of the spindle-shaped calluses at the two ends of the transplant, but both intermediary portions are fibrocartilaginous and permit free mobility. The callus uniting the fracture in the middle of the transplant consists entirely of irregular bony trabeculæ, and is small in amount both in its periosteal and endosteal portions. The periosteum of the entire transplant is alive, and has formed a thin layer of bone along its surface. The medullary cavity is filled by pale fibrous tissue except at the ends where there is a small amount of bony callus. The cells of the compacta of the transplant are dead and have nearly all been absorbed. Revascularization of the haversian canals has taken place and in a few places substitution of the old cortex by new bone has occurred. (Fig. 6.)

2. Fracture through a transplant minus periosteum.

10 day experiment. No. 174. Transplant one and one-half inches long.

Dissection shows good approximation about the fracture and a layer of organizing blood-clot along one side of the transplant. There is moderate enlargement of the ends of the fragments from periosteal callus formation but none at the ends of the transplant nor at the seat of fracture through its middle portion. There is fibrous union with free mobility of all three fractures. Microscopically, the transplant along one side is covered by an organizing blood-clot without any trace of callus formation even at the seat of fracture. Along al-

most the entire length of the other side where it came in contact with muscle there is a thin layer of spongy bony callus. This has formed from cells which have survived along the surface. Whether they were from the deeper portion of the periosteum which was not removed or from the surface of the cortex cannot be stated. The intermediary space of the fracture through the transplant is filled in by fibrous tissue and blood-clot. There is no callus formation in the ends of the medullary canal at this seat but a small amount at the seats of the other two fractures. About one-half of the bone-cells of the cortex are normal in appearance while the other half are either shrunken and stain poorly or have entirely disappeared. There is blood extravasation throughout the entire medullary cavity.

In this specimen there is the usual formation of callus from the ends of the transplant and a small amount along one side where there was no blood-clot to interfere with the nutrition of its superficial cells. However, this thin layer of callus is not comparable in amount to that which forms in a transplant with its periosteum intact. Union of the fracture in the transplant has just begun by the ingrowth of a small amount of fibrous tissue. Approximation of fragments was so perfect and extravasation of blood into the medullary canals so extensive that no callus was formed from the endosteum at the seat of fracture owing to the shutting out of nutrition.

87 day experiment. 173 L. Transplant one and three-fourths inches long.

Dissection shows good approximation and slight mobility at the seat of all three fractures. Small spindle-shaped calluses at the ends of the transplant but none at the seat of fracture in its middle portion. Longitudinal section through the entire specimen shows fibrous union of the upper and lower fractures. There is a small amount of ossified periosteal and medullary callus on the ends of the fragments but none on the ends of the transplant, and the intermediary calluses are fibrous except for some ossification proceeding from the ends of the fragments. There is no peripheral or medullary callus at the fracture in the transplant and union is by an intermediary callus which resembles the dense connective tissue surrounding the transplant. A small amount of ossification of this intermediary callus has begun along the fractured surfaces toward the medullary side. The bone-cells of the compacta have all been absorbed and the medullary cavity is filled with fibrous tissue. There has been no substitution of the dead cortex by new bone (Fig. 7).

These two sets of experiments show the very great rôle played by the periosteum in the healing of a fracture and the importance of perfect coaptation and immobilization for early bony union. Where periosteum was left on, there was callus formation at the seat of fracture in the transplant which underwent ossification before that which united the fractures at the ends. In one case there was bony union in 45 days while the two fractures at the ends were freely movable. On the other hand, where periosteum was removed, union was by a fibrous intermediary callus which showed only a small amount of ossification at the end of 87 days. Good approximation and some fixation were produced by impacting the irregular surfaces of the fracture in the transplant and these factors undoubtedly account for the more rapid union of the fracture through the transplant in the first series than of those at its ends where approximation and fixation were less perfect. This very conclusively shows the rôle of periosteum in the healing of a fracture and entirely rules out osteoconductivity as an explanation for the source of the callus uniting the fractures in the transplant, since in all of the experiments of the first series ossification of its callus was either complete or almost so, while the intermediary calluses at the ends of the transplant were still fibrous. The endosteum often forms little or no medullary callus at the fracture in the transplant because the bony ends are so closely approximated and impacted that the narrow intermediary space does not permit the entrance of sufficient serum to sustain the life of the endosteal cells.

VII. INFECTION IN TRANSPLANTATION

The influence of infection upon bone transplantation demands special consideration. It occurred in a number of experiments in varying degrees of severity and with different types of transplants. A severe infection with extensive suppuration usually results in death and sloughing out of the entire transplant, as in II, 2—Experiment No. 122. This happened a number of times but very few of these experiments were reported.

The severe infection may be limited to one end and result in death with sequestration of only that portion of the transplant. In the presence of a mild infection the transplant

may take but its subsequent behavior differs from that of one in a sterile field. When the transplant contains periosteum and medullary contents these structures may survive and have a reëstablishment of circulation despite the mild infection. The changes in the transplant resemble very closely those of an osteomyelitis. The surviving periosteum forms a layer of new bone about the cortex which both in its excessive amount and in its coarse spongy character resembles the involucrum surrounding the involved shaft in osteomyelitis. These points are well illustrated by Experiment 175 in V, 1. Absorptive changes in the dead cortex are very much accelerated. The surface is eroded, haversian canals are dilated, and since deposition of new bone does not keep pace with bone absorption the cortex is rendered somewhat porous in structure.

When periosteum is removed from the transplant, infection is much more apt to lead to failure because the cells of the bone itself have a much poorer chance than the periosteum to get sufficient nutrition and consequently are all killed by the infection with the result that there is no proliferation and regeneration from the transplant. The mild infection rapidly disappears, the transplant is retained, and substitution has to occur by an ingrowth of new bone from the ends of the fragments. Experiment No. 178 U, in II, 1, illustrates such a result before substitution has begun. If the infection is at all severe the ends of the shaft into the defect of which the transplant is placed are affected. Excessive callus formation and sequestration of a portion of the cortex may result as in the case of an infected compound fracture.

Slight infection of bone plus periosteum and marrow transplanted into the *soft parts* may stimulate osteogenesis from the surviving portions and hasten absorption of the necrotic cortex as seen in Experiment 175, IV.

BONE TRANSPLANTED INTO SOFT PARTS

When bone is transplanted into the soft parts conditions of nutrition, because of the close approximation everywhere of soft parts, are always as favorable as when it is transplanted into bony defecta. However, conditions with reference to function are entirely different and these cause the transplant to behave in an entirely different manner. In both instances there is functional adaptation of the transplant to its surroundings. In the case of bone transplanted into a bony defect functional irritation results in *activity hypertrophy* with subsequent union with the surrounding bone and transformation of the transplant. But bone transplanted into the soft parts has no function to perform. Functional irritation would consequently be reduced to a minimum, and hypertrophic changes, although they may be present at first, are slight. Atrophy of disuse sets in and leads to a gradual diminution in size of the transplant. This in case of larger pieces of compact bone may progress very slowly so that the transplant may persist indefinitely as an encapsulated mass.

The transplant in this set of experiments was varied in composition as follows: bone plus periosteum, bone minus periosteum, boiled bone, and periosteum alone. A segment of ulna varying in length from one-half to one inch was excised and that portion desired for transplantation was buried in the adductor muscles of the upper third of the thigh.

1. Bone plus periosteum and medullary contents.

There were five experiments in this series ranging in age from 9 to 84 days where the entire excised portion was transplanted.

9 day experiment. No. 135 R. Transplant three-fourths inch long.

Dissect on shows few gross changes. There is a small amount of fibrous tissue in the ends of the medullary canal and hæmorrhage in the rest of its extent; periosteum unchanged except for a small amount of spongy bony callus formation at one end. Most of the cells of the compacta have disappeared and others stain poorly, while a few are normal in appearance.

11 day experiment. No. 133. Segment one-third inch long.

Soft parts have become loosely adherent to the transplant, very little reaction about it. Ends of the canal filled with fibrous tissue. Periosteum on one side of one end stripped up for half a centimeter. This surface is covered over by granulation tissue. Periosteum slightly thickened throughout most of its extent and there is a thin layer of new bone

formed from the cambium layer in a few places. No ossification in the medullary callus of the ends. The marrow of the middle portion of the transplant is normal in appearance but contains some extravasated blood throughout. The cells of the cortex are, mostly, well preserved and some stain well but the majority stain poorly. Some of them have been absorbed.

33 day experiment. No. 170 L. Transplant one inch long.

The soft parts are thickened and adherent about it. The ends of the transplant are rounded off and covered by fibrous tissue. There is a layer of spongy new bone formed from the periosteum along most of its extent and a small amount bridging over the ends of the medullary cavity. There is also some new bone formation from the endosteum and about bony trabeculæ in the medullary cavity. The cells of the compacta are practically all absorbed leaving the lacunæ vacant. There has been considerable lacunar absorption of the dead cortex about the ends and some along the haversian canals which are partly revascularized and dilated. There is a large amount of fibrous tissue in the medullary canal and some new marrow accompanying the newly formed bone.

Because of the marked reaction, the thick surrounding capsule, the absorption and rather large amount of excessively spongy new bone formed, I think there was a mild infection setting up a slight inflammatory reaction in the surviving portion of the transplant.

67 day experiment. No. 134. Transplant three-fourths inch long.

Muscle loosely adherent about it. The ends of the transplant are rounded off and the medullary canals are closed over. The transplant is practically unchanged in size and is surrounded by a thin, densely adherent fibrous covering. Microscopical examination of a longitudinal section shows bridges over the ends of the medullary cavity to consist of a thin, incomplete layer of bony trabeculæ covered by a fibrous tissue and the periosteal surface of the transplant covered in most places by a layer of fibrous tissue with roughening and lacunar absorption along the surface. In other places there are trabeculæ of new bone but they are few while the absorption has decreased the transplant in size to a slight extent. The cells of the compacta are all dead and absorbed and the haversian canals are empty except the large ones which are filled by ingrowing fibrous tissue and blood-vessels. The medullary cavity is filled largely by fibrous tissue and contains a small amount of living marrow.

The striking features in this specimen are death of bone-cells and beginning absorption of the cortex. New bone formation is extremely small in amount, being present at the ends where the endosteum has tried to bridge over the medullary canal as occurs in an amputation stump.

84 day experiment. No. 135 L. Transplant three-fourths inch long.

It is surrounded by a thin fibrous covering; the edges of the ends are rounded off and the ends of the medullary cavity are bridged over. Segment seems to be decreased in size particularly toward one end. Longitudinal section shows the bridges over the ends of the medullary canal to consist of a small amount of new bone about the walls of the canal covered over by an outer fibrous layer. The periosteal surface and ends of the cortex are covered by a thin fibrous layer which in most places has produced considerable absorption of the cortex but in two or three places there is a very thin layer consisting of one or two lamellæ of new bone between this fibrous layer and the cortex. The old cortex is dead and all of its cells are absorbed. There are numerous dilated haversian canals scattered throughout the cortex with a single circumferential layer of new bone formed in some of them.

In this series of experiments, periosteum has remained quite generally inactive, the bone-cells have died, and absorption of the dead cortex is taking place. Endosteum has formed only a small amount of new bone at the ends in an endeavor to close the ends of the canal. This seems to have been about the only stimulus for any new bone formation aside from the presence of an infection in Experiment No. 170 L.

2. Bone minus periosteum transplanted into soft parts.

52 day experiment. No. 169.

Very similar in every way to 54 day experiment.

54 day experiment. No. 130. Transplant one inch long.

It is surrounded by a layer of fibrous tissue, and the ends are somewhat rounded off and bridged over. There is no new bone formation along its periosteal surface but a small amount of absorption has taken place along almost the entire extent of the cortex. The cells of the compact bone are all dead and have been absorbed. The bridges over the ends consist of a small amount of new bone in their inner portions and a fibrous tissue in their outer. The medullary cavity away from the ends is filled partly with dead marrow and fibrous tissue and partly with newly formed bone-marrow. There is a thin layer of new bone consisting of only one or two lamellæ along the endosteum at the ends of the

medullary canal. Some of the haversian canals of the cortex are dilated and in a few places circumferential lamellæ of new bone have been formed.

94 day experiment. No. 155. Transplant one inch long, consisting of one-half of a segment of the shaft split longitudinally.

It is somewhat diminished in size and pointed at one end. It is surrounded by a fibrous capsule with muscle firmly adherent and shows considerable absorption about the ends and in places along its periosteal and endosteal surfaces. The cells of the old cortex are dead but the shrunken nuclei of many of them fill the lacunar spaces. There is no new bone formation along the surface of the transplant except for a small amount toward the ends on the endosteal side and in some of the large superficial porous spaces and canals where layers of bone consisting of from one to three lamellæ may be seen.

Death of bone-cells and absorption of the cortex are the predominating features in the specimen.

151 day experiment. No. 137 R. Transplant one-half inch long.

Dissection shows it loosely adherent to the muscles and slightly decreased in size. The cells of the bony cortex are all dead and absorbed. The ends and edges of the transplant are rounded off and it is surrounded by a thin fibrous capsule. There is slight evidence of lacunar absorption in places along the periosteal surface and ends while in other places there is a thin layer of one or two lamellæ of new bone. There is some new bone along the endosteum toward the ends but no bony bridge over one end and only a suggestion of one at the other. The medullary cavity is filled throughout with fibrous tissue. The larger haversian canals are filled with connective tissue and in a few places one or two concentric lamellæ of new bone have formed in them. This specimen is encapsulated and absorption has been very slow. Only a trace of bone proliferation is to be seen about the surfaces.

237 day experiment. No. 137 L.

Transplant one-half inch long has diminished in size almost one-half and is surrounded by a fibrous layer with muscles firmly attached. The edges of the ends are rounded off and the medullary cavity is bridged over by a very thin incomplete layer of bony trabeculæ. There is a thin layer consisting of one or two lamellæ of new bone along most of the extent of both the periosteal and endosteal surfaces, and of the cut surfaces of the ends of the cortex. Evidences of lacunar absorption are not marked. The cells of the compact cortex are dead and have all been absorbed. There is revascularization of the haversian canals and in some of them one or two circumferential lamellæ of new bone have been formed. The medullary cavity is filled largely by normal regenerated bone-marrow and in the rest of its extent by fibrous tissue.

In this specimen there has been slight new bone formation bridging over the ends of the medullary canal and along the cortical and medullary surfaces, and to a slight extent within the haversian canals. There has also been some regeneration of bone-marrow in the medullary canal. However, the retrogressive and absorptive changes are the striking ones, since the specimen had decreased in size about one-half. It is possible that some of the new bone about the surface is heteroplastic in origin, having formed from the connective-tissue capsule as in the case of the older specimens of boiled bone.

3. Boiled bone transplanted into soft parts.

10 day experiment. No. 170 L.

Transplant two-thirds inch long surrounded by granulation tissue. Cells of cortex all dead, and mostly absorbed. No new bone formation anywhere. Fibrous tissue growing into the medullary canal and larger pores of the somewhat spongy cortex. There is some slight absorption about the surface of the transplant.

4. Periosteum free into soft parts.

In six experiments ranging in age from 13 to 199 days the periosteum removed from excised segments of the ulna one inch long was transplanted into the adductor muscles of the thigh.

In the 13-day experiment the periosteum was alive and had proliferated, forming a small mass of tissue resembling fibrous callus, but in none of the sections examined was there any new bone.

In three specimens, 38, 118, and 164 days old, there was a nodule of bone at the seat of implantation varying in size from a pinhead to a grain of wheat. In two specimens, 42 and 199 days old, no bone was present and the only remains of the implanted periosteum was a small mass of scar tissue.

The fact that periosteum is removed from its bone and in a location where there is no demand for bone formation accounts for the entire absence of or inconsiderate amount of new bone formation in these experiments. This failure to form bone, at least in any amount, when in an abnormal location, is no proof of its inability to do so when in its normal place and when there is a demand for new bone formation.

52 day experiment. No. 169. Transplant one-half inch long.

It is loosely adherent to the muscle and surrounded by a very thin layer of fibrous tissue. There is no appreciable decrease in size. Micro-

scopic examination of a longitudinal section shows the cells of the compacta are all dead but many of them have been fixed by the heat and are still present taking a weak nuclear stain. There is no new bone formation anywhere to be seen. Everywhere about the surface and ends there is lacunar absorption of the dead cortex. The marrow cavity is filled throughout with fibrous tissue.

250 day experiment. No. 138 B.

Transplant one-half inch long and is decreased in size almost one-half. It is surrounded by a layer of fibrous tissue and in places there is roughening and absorption of the dead cortex. In other places along the cortex and in the canals there are layers of new bone consisting of one or two superimposed lamellæ. This is heteroplastic bone which after months forms from the surrounding connective tissue about pieces of dead bone, as observed by Barth and others.

From these experiments we may conclude that boiled bone transplanted into the soft parts gradually undergoes absorption.

5. Strip of periosteum one and one-half inches long cut from the inner surface of the femur and embedded in the adductor muscles above, but left attached to the bone at its lower end.

84 day experiment. No. 156.

Dissection shows a small fibrous cord at the seat of the embedded periosteal flap extending from the inner condyle of the femur obliquely outward and upward into the adductor muscles. There is no evidence of bone formation in the course of this periosteal flap and microscopical examination shows it to consist entirely of fibrous tissue.

94 day experiment. No. 155 B.

Dissection shows that the upper part of the periosteal flap has formed a large bean-sized and shaped nodule of new bone within the substance of the adductor muscles, but the lower part has been converted into a fibrous band about 1 centimeter long uniting the bony nodule to the internal condyle of the femur. The surface of the femur from which the periosteum was removed is covered over by reformed periosteum and shows no bony thickening anywhere (Fig. 15).

Pochhammer in a series of similar experiments obtained extensive new bone formation when a periosteal flap plus blood-clot or fibrin was embedded in the muscle, but little or none when periosteum alone was used. As shown by Marchand in his studies upon wound healing, blood-clot or fibrin located in any of the tissues of the body stimulates cell proliferation on the part of the connective tissues until the clot or fibrin has been substituted. When periosteum is in the field, as in these experiments, it proliferates, forms callus, and later ossifies. The formation of a hæmatoma in Experiment 155 B, and not in Experiment 156, may have been the cause of the difference in results in the two cases.

These experiments show that while the same tissues survive when bone is transplanted into the soft parts as when transplanted into a bony defect the subsequent course of the surviving and necrotic portions is different. In a bony defect the surviving portions hypertrophy, help unite the transplant in position, and replace the necrotic parts by new bone. In the soft parts they proliferate very little and form only a small amount of new bone. The dead cortex does not undergo substitution by new bone but the entire transplant atrophies from disuse and is very slowly absorbed. In behaving this way bone simply obeys the same laws as the other tissues of the body. The law of *functional adaptation* founded by Wilhelm Roux may be briefly stated as follows: There is a distinct relation existing between the form, size, and structure of a tissue or organ and the function it has to perform, and a change in any one of these factors results in corresponding changes in the others. *This law holds for transplanted tissues as well as for those under normal conditions. When a transplant is placed in a defect where it is needed and can functionate, the surviving cells hypertrophy, substitute the necrotic portion, and take part in uniting it in its new location.* This was shown particularly well by Lewis and Davis in the case of tendon transplanted into a tendinous defect. *Tissues transplanted into useless locations, although the great bulk of their cells may survive, hypertrophy but little or not at all and slowly diminish in size.* Thus tendon transplanted into the subcutaneous fat contracts into a ball and gradually disappears. The same rule holds for fascia, fat, and even for the ductless glands with relation to their internal secretions as Halsted showed that parathyroid transplants would not long survive and functionate unless the amount of parathyroid tissue in the animal was first decreased to a point where there was partial parathyropriva.

Violation of this law results from the in-

fluence of outside factors. Thus the occasional production of considerable bone by periosteum transplanted into the soft parts may be due to the presence of a blood-clot as in the thigh muscles, to the irritation of a mild infection as in Experiment No. 170 L, or to functional irritation in an abnormal location as may possibly be the case in McWilliams' experiments where rib periosteum formed new bone when transplanted into the abdominal wall, the respiratory abdominal movements simulating conditions existing in the thoracic wall which result in the regeneration of ribs where subperiosteal resection has been performed.

My experiments in transplantation into the soft parts are entirely in disaccord with those of Axhausen. He claims that the living portions hypertrophied and that the compacta which dies is substituted by new bone. None of his experiments were sufficiently old for him to judge of these changes and to see that the transplant gradually decreased in size. He entirely disregarded Roux's law of functional adaptation and concluded that the transplant behaved about the same whether in the soft parts or in a bony defect. These experiments as well as those of Brown and Brown disprove these claims.

SUMMARY

1. Osteogenesis in bone repair occurs from the inner layer of the periosteum, from the endosteum, and to a much less extent from bone-cells and fibrous contents of the haversian canals.

2. Viability of the cells of the transplant is dependent largely upon their ability to get nutrition and to some extent upon their degree of cell specialization. Periosteum and endosteum, being superficially located, receive sufficient nutrition to survive and proliferate. The great mass of bone-cells being away from the surface and surrounded by an extensive and difficultly permeable calcified matrix gradually undergo necrosis and absorption. A few about the periphery and lining the larger vascular spaces as well as the fibrous elements of the latter may survive and proliferate. Blood-forming cells of the marrow, despite their favorable nutrition and probably because of their greater degree of specialization, gradually undergo necrosis.

3. The subsequent changes which the transplant undergoes depend upon its composition and location. According to Roux's law of functional adaptation a transplant placed in a useful location, i. e., a bony defect, undergoes progressive changes while one in a useless location, i. e., soft parts, undergoes chiefly retrogressive changes and is gradually removed.

A. Transplantation into a bony defect.

Functional demand stimulates the surviving cells of the transplant to osteogenesis. Callus forms at either end which helps unite the transplant and the fragments. Creeping substitution of the dead cortex gradually occurs by the ingrowth of capillaries with dilatation of the haversian and Volkmann's canals, absorption of the old bone, and deposition of new bone in its place.

(*a*) When periosteum and endosteum are left on, the transplant contains the greatest number of living osteogenetic cells. Consequently union between the ends and substitution of the dead cortex occurs most constantly and rapidly.

(*b*) When periosteum is removed, osteogenesis producing union and substitution occurs from the endosteum and few surviving cells of the cortex, but the process is much slower than when periosteum is left on.

(*c*) When both periosteum and endosteum are removed, new bone formation from the few surviving cells is slight, and union with the ends of the fragments and substitution of the dead bone are very much delayed.

If such a transplant is cut into small pieces before implantation more cells survive because of the increase in surface and facilities for nutrition and greater functional irritation. Consequently, considerable callus forms from each piece and, fusing with that from the others and from the ends of the shaft, rapidly restores the continuity of the shaft. Ossification of the callus proceeds from the surface of each piece and substitution of their dead portions gradually occurs.

Axhausen's claim that osteogenesis does not occur from transplanted bone devoid of periosteum and endosteum is incorrect.

Equally erroneous is the old view of Barth, now advocated by Murphy, that there is no osteogenesis from any portion of a transplant, substitution occurring entirely by an ingrowth of new bone from the fragment ends.

(*d*) Periosteum transplanted into ulnar defects and in subperiosteal ulnar resections failed to regenerate bone and restore the shaft, but in subperiosteal resections with reimplantation of cortex either alive or after boiling it formed a layer of callus about the reimplanted portion. Subperiosteal resection of the humeral shaft in the young was followed by regeneration of the shaft.

Periosteum gets its chief impulse for osteogenesis not from an injury to itself but from the injured bone to which it is attached or intimately related and which demands repair.

B. Transplantation into soft parts.

The same portions survive as in a bony defect but since there is no functional demand for bone in this location little proliferation or substitution occurs and the transplant is gradually absorbed.

Transplanted periosteum produces little or no new bone for the same reason.

4. The presence of an infection, if severe, results in death and failure of the transplant; if mild, there is set up in it an osteomyelitis with excessive proliferation and absorptive changes, but the transplant takes and is functionally a success.

5. A fracture through a transplant unites by callus formed from the surviving cells of the transplant in the vicinity of the fracture.

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INTRAVENOUS ETHER ANÆSTHESIA

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THE intravenous administration of a narcotic for the purpose of general anæsthesa has stood the test, not only of numerous experiments on animals, but also of practical use in the treatment of human beings.

The same thing has been true of intravenous anæsthesia as of everything else new in medical science: if it is unusual and apparently not altogether without danger, it is taken up with reserve and submitted to a test only with great caution, at least in Germany. Only a relatively small number of surgeons have thoroughly tested this new method of general anæsthesia proposed by Witzel and others and first successfully used by Burchhardt on human beings, and only a few have used it to any extent on their patients. Even in the textbook of surgery recently published by Bier, Braun and myself, it is not mentioned.

This has led me to discuss this subject briefly before this scientific association of American surgeons and to recommend that the eminent surgeons of America test a method of anæsthesia which gives excellent results in many cases if used for the proper indications and if the technique, which is not difficult, is properly carried out. In certain cases, in my opinion, it is not excelled by any other method of general anæsthesia. Though our method of inhalation anæsthesia is so well developed that its dangers are slight, yet we often find patients requiring surgical treatment whose general condition is so bad that the inhalation method markedly increases the danger of operation, and local anæsthesia often does not produce complete insensibility to pain. For such cases intravenous anæsthesia is a great gain.

The reason intravenous anæsthesia has so slowly gained a place in surgery may be that there has been a fear of thrombus formation at the place of injection and of embolus proceeding from it. Küttner observed 23 cases of pulmonary embolism which showed threatening symptoms and cyanosis, and Clairmont and Denk of von Eiselsberg's clinic, performed experiments on animals that seemed to show that intravenous anæsthesia was uncertain and dangerous. These facts based on theoretical grounds have increased the fear of the dangers of this method of anæsthesia.

The experiments we have thus far made with the intravenous administration of ether have been so unusually favorable that it seems to me desirable that it should come into general use.

We have used this method of anæsthesia in 250 cases, which is, of course, a small number in comparison with the several thousand cases of general anæsthesia we have in the course of each year. We entered upon our experiments with great caution, carefully selecting the cases and accurately testing the effect of the mixture of salt solution and ether on the general condition of the patient, on the kidneys, heart, lungs, and vessel-walls. We were convinced in advance that this method would never supplant the scopolamine morphine, ether, or chloroform anæsthesia, which we carry out with Roth-Dräger's apparatus, but in the course of our experience we have become convinced that for certain groups of cases the intravenous anæsthesia, by the method of its application and the stimulating effect on the organism, has superior results, and cannot be replaced by any other method.

Intravenous anæsthesia is specially fitted for operations on the face and head, particularly in the mouth and pharynx, on the upper jaw and at the base of the skull (tumors of the hypophysis, etc.), as well as for operations on the neck. In such cases the anæsthetist is in the way of the operator. Anæsthesia is often incomplete because of the necessity of frequently putting on and taking off the mask, which is in the way of the operator. This is completely avoided by intravenous anæsthesia. There are great advantages in a uniform, quiet anæsthesia, which is conducted far away from the field of opera-

tion, which enables us unhindered to carry out operations on the face, mouth, etc., and which at the same time increases the strength of the patient by the constant influx of salt solution in operations where there is a great loss of blood.

The method has turned out surprisingly well in 30 cases of tumors of the upper jaw, of the larynx, thyroid, base of the brain and skull, carcinoma of the tongue and tonsil, plastic operations on the nose, etc., because it has given a uniform, quiet anæsthesia that did not interfere with the field of operation or disturb the operator and his assistants.

Moreover, the intravenous ether anæsthesia had advantages in the case of patients who were weak, or who, from the long duration of their disease, were much exhausted and emaciated. These are the patients to whom we often have to give an infusion of salt solution at the beginning of the anæsthesia in order to increase their strength to a certain degree and make the giving of general anæsthesia possible. When, with patients in such poor condition, we are placed in a position to add to the salt solution entering their veins another stimulant that not only increases the effect of the solution, but at the same time anæsthetizes the patient without danger, this seems to me to be the ideal method of anæsthesia for this group of patients.

Such patients often leave the operating room after the operation with a much stronger pulse, often with remarkably good heart action and with a fresher appearance than when they came in. They awake from the anæsthesia quickly and without any unpleasantness. We have never observed nausea and vomiting after intravenous ether anæsthesia, a factor that is not to be disregarded in weak patients after laparotomies. The comparatively better condition after this form of anæsthesia is readily explained by the smaller amount of ether.

Intravenous anæsthesia was used in 100 cases of carcinoma of the œsophagus and cardia, in malignant tumors of the stomach, benign stenosis of the pylorus, in 12 tumors of the rectum and cæcum, in total extirpation of the carcinomatous uterus, in extra-uterine pregnancy, in malignant tumors of the abdominal cavity, in kidney diseases, diffuse peritonitis, in patients with fungus of the knee-joint, and with tumors of the thigh.

As to the important question of the dangers of intravenous anæsthesia, I believe that they have been greatly exaggerated from theoretical considerations. It was assumed in advance not only that there would always be a thrombus formed at the site of injection, but that embolism would frequently result. These assumptions are, of course, justified, and caused us to proceed with the greatest caution in the carrying out of this new method of anæsthesia. The formation of thrombus would be the weakest point in intravenous anæsthesia if it were to be feared that emboli would often result from it.

What are the actual facts in the experiments thus far with regard to the formation of thrombi and embolism following it? Like Burchhardt we have never had a case of pulmonary embolism among our patients anæsthetized intravenously, but in the early days of its use we frequently had local thromboses at the site of injection into the vein. In three cases there were complaints soon after the operation of pain in the region of the injection, which stopped after a few days. The thickened vein could be felt for a distance of 3 to 5 cm. We have never observed such symptoms in other cases.

As we were dealing almost exclusively with patients in very poor condition, many of them suffering from advanced carcinoma, and succumbing to the disease sooner or later after operation, in many of the cases we had the opportunity of controlling the clinical observation by autopsy. The lungs, heart, and kidneys showed no special pathological findings, at least none that could be attributed to the anæsthesia, but in the first cases that came to autopsy there was thrombosis at the site of injection. In those cases where the ether-salt solution had been allowed to enter the veins as needed, and the stream was interrupted from time to time, there were tolerably thick, hard thrombi, partially stopping the collateral vessels. In the other cases the thrombi were shorter and softer, and not more pronounced than those that

exceptionally follow the injection of simple salt solution, and frequently follow the injection of digalin or adrenalin.

In a later group of intravenous anæsthesias in which we used the improved method of a continuous stream of physiological salt solution, and were able to observe the effect several times at autopsy, we did not see a single case of thrombosis.

It seems to me that the danger of the consequences of thrombus formation at the site of injection is exaggerated. Since we have given greater attention to the effect of simple salt solutions, especially those containing adrenalin and digalin, we find that there is almost always the formation of a thrombus in the use of solutions with a medicinal content, but that pulmonary embolism never results from them. The appearance of an embolus originating from a thrombus of the upper extremity seems to be an unusual occurrence. Certainly our present method of giving medicines intravenously would be decidedly limited if there were any danger worth mentioning of embolism resulting from it. If there was any reason to fear the formation of these slight thrombi in the veins of the upper arm, we would have to give up the frequent administration of salt solution containing digalin or adrenalin, which is, of course, regarded as being without danger. Certainly no one contemplates giving up this valuable addition to our methods of treatment, and no one has had any cause to do so by any injury experienced.

The same thing is true of the dangers arising from the addition of ether to the solution; they are slight, even though the ether, like digalin or adrenalin, is a substance that injures the vessel-walls to a certain extent. When we have succeeded by further perfection of the technique in reducing thrombus formation to a minimum or even overcoming it completely, this new method of anæsthesia will be freed still more from the dangers attending it.

As to the value of the intravenous administration of salt solution as such, to the organism, we are ardent supporters of this therapeutic measure which has saved so many human lives. We use it in large quantities and a great number of times, so that when necessary we have given as much as 18 liters within 24 hours without danger to the patient; on the contrary, it has saved life. We interrupt the giving of salt solution, and also the intravenous anæsthesia, when œdema of the lower eyelids and the sclerotic conjunctiva occurs. The amount of solution to be injected is an important point in intravenous anæsthesia, and naturally it varies with the strength of the individual. In a weak, dried-out body that eagerly absorbs water we can give relatively large quantities of fluid, but we reach the limit much quicker in a strong patient with a well-filled vascular system.

As to the indications for intravenous anæsthesia, they are, as I have said, thin and weak individuals (carcinoma, ulcer of the stomach, etc.), those who have undergone hæmorrhage (extra-uterine pregnancy, injuries, etc.), as well as collapsed patients (peritonitis, etc.). Furthermore, it should be used in operations on the neck and head (throat, tongue, etc.), and I believe it will meet with greater success than any other known method of anæsthesia.

In very strong individuals the inhalation method should be given the preference, or when the above-mentioned indications, head and neck operations, make it seem desirable the salt solution containing the ether should be allowed to flow into the veins very slowly and with the greatest caution, and it should be combined with isopral.

Intravenous anæsthesia is contra-indicated in arteriosclerosis, in which there is generally a high blood-pressure, in severe myocarditis and in general plethora.

We have never observed complications in the heart and lungs, except in one case where there was a pulmonary and laryngeal tuberculosis, which seemed to be made worse by the intravenous anæsthesia. In amyloid disease of the kidney the albumin excretion was slightly increased the first few days after the operation; in the other cases the urine remained free from albumin, blood, and kidney constituents.

In a great number of the cases, immediately after the operation, blood was withdrawn from the vein of the arm of the opposite

side. Neither microscopically nor spectroscopically could any changes be demonstrated in the red blood-cells, in their color or hæmoglobin content. This is due to the fact that the 5 per cent ether solution does not attain its full effect, as only 4 per cent of the ether mixes with the water and a part of it escapes from the open vessel containing the solution; if this is covered it collects over the the water. This can also be demonstrated by holding a lighted match over the vessel, when the ether will burn with a bluish flame. Not more than a three and one-half per cent ether solution flows into the vein. Moreover, the greater part of the ether given is excreted again directly through the lungs, as can be demonstrated by the odor of the expired air soon after the beginning of the anæsthesia. Even on observing the patients for a long time during convalescence nothing was ever found which indicated an injurious effect of the intravenous anæsthesia.

This form of anæsthesia is very pleasant for the patient. Headache, vomiting, or other disagreeable after-effects were never observed. In many cases the patients themselves asked to be anæsthetized "through the arm," because they had heard from their neighbors in the ward the pleasant effects of this method. In seven cases intravenous anæsthesia was given patients a second time at their own request when another operation had to be performed.

Experience and practice is of great value in the technique of administering intravenous anæsthesia, as it is in lumbar anæsthesia. All of our patients from about the 20th to the 63d year are given before the operation the usual dose (3 to 5 decimilligr.) scopolamine and 1 centigr. morphine, whether inhalation anæsthesia or some other method is to be used. In twilight sleep the patient's eyes are covered on the operating table and, with the usual antiseptic precautions, the median vein laid bare and the cannula inserted as in the giving of salt solution. In order to avoid the formation of thrombus we do not interrupt the stream of solution. Two glass vessels are placed on a standard, one containing 4 per cent ether solution, the other physiological salt solution of 41 per cent strength. The tubes from both of these vessels are united in a Y-shaped glass tube, which has on its lower limb a piece of rubber tubing carrying the cannula and a stop-cock that is easy to regulate. By means of the latter it is possible to give a uniform injection of small quantities of fluid. For instance, after a sufficient amount of the ether solution has been given to induce anæsthesia, the ether solution is shut off by means of a clamp, while the physiological salt solution is allowed to flow slowly, until the return of the reflexes indicates that more ether is needed. Then the salt solution tube is closed and the ether tube opened.

This arrangement makes it possible to give accurate dosage, because the amount of solution used can be read from the graduated glass vessels, and by means of the stop-cock the rapidity of the flow into the vein can be accurately regulated. The regulation is most suitably and easily accomplished by means of a suitable, bored glass stop-cock.

The stage of tolerance, which permits the operation to be begun, generally sets in after ten minutes, in very weak patients often after four or five minutes, when 100 to 300 grammes of fluid, corresponding to 4 to 15 grammes ether, has been given. In some cases this takes place after one and one-half to two minutes. Aside from slight movements of resistance we seldom saw any stage of excitement. Only in one case, that of a 24-year-old man who had been anæsthetized often, the severity of the stage of excitement made it impossible to continue the intravenous anæsthesia. In three other cases of very excitable men or drinkers, a small amount of chloroform was given and then the intravenous anæsthesia continued without interruption.

At the beginning of our experiments, before we began to give the continuous injection, we had slight cyanosis twice, and once asphyxia which demanded artificial respiration. Probably from lack of experience too much ether was given in a unit of time. The cyanosis stopped immediately after the ether solution was cut off. I mention this especially in opposition to Dumont's opinion that in intravenous an-

æsthesia the administration of the anæsthetic should be stopped at once with the appearance of the slightest symptom of danger,—not less quickly, but perhaps even more quickly, than in inhalation anæsthesia.

Almost without exception the anæsthesia proceeded very quietly; the breathing was uniformly good, the pulse stronger, because of the giving of the solution. We had no accidents, aside from the insignificant disturbances mentioned.

The longest duration of an intravenous anæsthesia was in a man in extremely poor condition with a carcinoma of the cardia; besides an extensive resection of the stomach it was necessary to remove the cardia and 10 cm. of the œsophagus. Within 140 minutes 1700 ccm. of the ether solution, or 85 gm. of ether, were given. I believe that the favorable course of this extensive operation and the recovery after resection of the carcinomatous cardia was due to the stimulating effect of the intravenous anæsthesia. In another patient, from whom a tumor of the base of the brain was removed by temporary resection of the upper jaw, we used in 105 minutes only 900 ccm. of the ether solution, or 45 gm. ether; in an operation for a ruptured aneurism of the abdominal aorta, which was sutured and required one and one-half hours, we used about 60 gms. ether. In one case 3700 gms. of fluid was given; the patient recovered.

In order to hasten the beginning of anæsthesia, especially in drinkers and strong individuals, we have combined the ether for intravenous administration with other narcotics. Of the different ones used, veronal, hedonal, and isopral, we prefer the latter, first used and recommended by Burchhardt, because it seems to have fewer injurious by-effects. Intravenous hedonal anæsthesia, which has been chiefly used by Fedoroff and other Russian surgeons, seems to me to be not entirely without danger for the respiratory center, heart, and kidneys, and experiments by Beresnegowsky in Tomsk show that even in pure isopral anæsthesia there were injurious effects on the heart, liver, and kidneys.

I would not recommend an intravenous anæsthesia of pure isopral, as this agent when used abundantly and for a long time causes a marked lowering of the blood-pressure and seems to have an injurious effect on the respiratory center; but the use of a one to one and one-half per cent isopral solution, to begin and hasten intravenous ether anæsthesia, has given good results and when carefully and correctly used has no disadvantages.

Since October, 1912, we have used this combined method exclusively and have tried it in 80 cases. A third glass cylinder is added according to Burchhardt's directions, which is filled with sterilized isopral solution. The isopral is used in a concentration of one to one and one-half per cent in Ringer's solution. About 24 hours are necessary for the solution, as it can only be heated to 30 degrees. Slow administration of the isopral solution, not more than 100 gms. in five minutes, is important. If it is given too quickly or in too great quantities, asphyxia or cyanosis may occur, which disappear as soon as the flow of the solution is stopped. In only one case of inoperable carcinoma of the stomach, with dissemination in the peritoneum in a patient in very poor condition, the respiration stopped while the pulse was strong and full; artificial respiration had to be performed for a short time. This was caused by giving the isopral solution too quickly. In most cases 80 gms. of isopral solution was sufficient to induce the stage of tolerance in three to five minutes. More than 150 gms. of the solution, containing one and one-half to two and one-fourth gm. isopral is not to be recommended. After the beginning of anæsthesia, by simply turning the valve-cock the anæsthesia is continued with ether. In weak patients the ether anæsthesia alone is sufficient.

We believe from our experience that intravenous ether anæsthesia is a form of anæsthesia which, when given for the proper indications, is not excelled by any other form of anæsthesia in a large group of cases. I might even say that for many cases it is the ideal anæsthetic, for, besides the fact that such a small amount of the anæsthetic is

necessary, it has an active, stimulating effect, which cannot be said of any other form of anæsthesia known.

The addition of a one to one and one-half per cent solution of isopral is an excellent supplement in the induction of intravenous ether anæsthesia, because it brings about the stage of tolerance more quickly, especially in drinkers and patients who are hard to anæsthetize. Too quick an injection of the solution, or too great doses, may cause a fall in the blood-pressure, or cyanosis. We have never yet seen any ill effects from the intravenous isopral-ether anæsthesia.

THE RESULTS OF OPERATION (LARYNGOFISSURE) FOR INTRINSIC CANCER OF THE LARYNX[1]

By PROFESSOR E. SCHMIEGELOW, Copenhagen, Denmark

THE surgical treatment of intralaryngeal cancer gives exceedingly good results, especially when compared with those obtained by surgical treatment of cancer in other internal organs.

On examining the facts we find this to be due to the peculiar manner in which intrinsic cancer of the larynx originates, develops, and spreads, as was originally pointed out by my friend, Sir Felix Semon. It would be interesting historically to consider the development of the pathology, diagnosis, and treatment of intrinsic cancer of the larynx, but lack of time forbids me doing so. You must, however, permit me to state here in London, speaking to an assembly of prominent American and English surgeons, that, in my opinion, the whole of our present knowledge of the diagnosis and treatment of this disease is founded on the works of Semon and Butlin, who, towards the end of the last century, entirely revolutionized our views with regard to the malignancy of intralaryngeal cancer. Before their day the surgical treatment of this disease had always been regarded as almost hopeless, but Semon showed us that the chief reason for this was that the disease was always diagnosed too late and therefore too far advanced to give any good operative result.

Having further learned that intralaryngeal cancer in the great majority of cases appears as a primary cancer of the vocal cord, and therefore soon causes hoarseness, we have means of recognizing the disease at an early stage of its development, while still limited to the vocal cord, and so of a probable radical cure by removing the diseased vocal cord through a laryngofissure.

To illustrate the frequency of primary cancer of the vocal cord I wish to draw your attention to this table of sixty-six cases of intralaryngeal cancer which have come under my observation:

TABLE A. PRIMARY SEAT OF INTRALARYNGEAL CANCER

No specified localization	in 18 cases
Vocal cord	in 36 cases
Sinus Morgagni	in 2 cases
Arytenoid region	in 4 cases
Epiglottis	in 1 case
Ventricular band	in 5 cases
	66 cases

In the first eighteen cases the primary seat of the disease could not be localized, as the tumor had extended too far into the larynx when first observed.

The table clearly shows that cancer of the interior of the larynx, in by far the majority of cases, originates as a growth of one vocal cord, generally in the central part of it, and that it can therefore be radically removed. If, however, the disease has extended to the anterior commissure the prognosis becomes more serious, as under these circumstances the thyrotomy cuts through the growth and may possibly be followed by a recurrence.

Those cancers of the larynx which do not primarily attack the vocal cords have, on the contrary, a bad prognosis; first, because they very often are not discovered until they have spread so far that there is no possibility of a

[1] Read before the Clinical Congress of Surgeons of North America, London, July 27, 1914.

radical cure by means of a laryngofissure; secondly, because these extracordal cancers are generally of a more soft medullary character, growing quickly and with greater tendency to involvement of the neighboring lymphatic glands.

The only exceptions to this are the pedunculated adenocarcinomas which spring from the arytæno-epiglottic folds. Of these I have seen three cases which had a relatively good prognosis and could be treated endolaryngeally with favorable results.

Having made the diagnosis by means of laryngoscopic inspection, supported by microscopic examination of a portion removed through the mouth, the growth should be removed as soon as possible by means of a laryngofissure.

This operation should be performed as indicated by Butlin and Semon, who about 1890 inaugurated this treatment and proved that this comparatively safe operation was sufficient, if performed soon enough.

I myself, following their instructions, chiefly operate in the folowing manner:

The operation is always performed under general anæsthesia. I begin with morphium-ether and make a low tracheotomy. Hahn's tampon-cannula is introduced and the narcosis is continued with chloroform. The thyroid cartilage having been divided and the interior of the larynx opened, I fill the pharynx with sterilized gauze introduced from below through the split larynx, in order to prevent the saliva from descending and interfering with the scene of action. According to Semon, the larynx is packed with gauze soaked in a 10-per-cent solution of cocaine, to which I add a few drops of a 1 Pr. mille solution of adrenalin in order to anæsthetize the mucous membrane of the larynx and make it bloodless. Then the neoplasm, together with the whole diseased vocal cord, is removed by means of knife and scissors.

All the diseased area having been removed and the bleeding stopped, we formerly filled the larynx with a tampon of iodoform gauze; but since Butlin has taught us to give up tamponading and to close the thyrotomy wound at once, the results of operation have been much better.

The patients are now able to swallow on the day of operation and can leave their beds a few days later. This, of course, is of the greatest importance in preventing complications in the lungs, especially, in elderly people. My two eldest patients, respectively 71 and 74 years old, were able to leave their beds on the second day, and they are both alive and well now, at the age of 80 and 76 years.

Thyrotomy could only be performed in thirty-three of my cases treated up to 1912, as shown in the following table (Table B):

TABLE B. RESULTS IN 70 CASES OF CANCER OF LARYNX

EXTRINSIC AND INTRINSIC

		Cured	Died or Relapsed
No treatment	10	0	9
Tracheotomy	8	0	8
Endolaryngeal removal	5	1	4
Thyrotomy	33	18	15
Subhyoid pharyngotomy	1	0	1
Partial resection of the larynx	4	0	4
Total resection	9	1	8
	70	20	40

The result of these thirty-three thyrotomies was that twenty-eight patients survived the operation, while five died from pneumonia, due chiefly to post-operative hæmorrhage.

Of the twenty-eight patients operated upon, recurrence took place in ten cases, while eighteen are alive and well. These eighteen had the carcinoma entirely limited to the vocal cord and the diagnosis was made at an early period of the disease, with only two exceptions. The first of these was a man aged 44 years (see Table D, No. 11) who had a cancer of the posterior wall of the larynx, and whom I was able to follow for three years after the operation, when I lost sight of him. The second was a man, aged 28, suffering from an epithelioma of the left ventricular band, anterior commissure, and the anterior part of the right ventricular band. This patient I operated on fourteen years ago, since which time he has been on an expedition to the North Pole and is still alive and well.

The last four patients were operated in 1912 and have therefore been under observation only about two years since the operation. But they were all cases of quite limited

epithelioma of the vocal cord and were operated so early that there is not much chance of recurrence.

Patient No. 7, a man aged 61, was operated in 1905 for a cancer of the vocal cord. During the following seven years his larynx remained perfectly healthy, but he now has a quickly growing cancer in the throat requiring tracheotomy. Ought this to be considered as a recurrence or as an accidental cancerous infection of a larynx which has kept perfectly healthy for seven years after operation? Personally, I am inclined to look upon it as an accidental reinfection. In all the other cases of recurrence this took place within a year after the thyrotomy.

The functional result was exceedingly good in all cases. The voice was strong, generally sonorous, but in a few cases hoarse. The man aged 71 was operated on in 1905; I saw him last in 1913. He was then 79 years old and had a strong, healthy voice.

A clergyman, aged 55, who was operated in 1896, fulfilled his duties for eight years and preached every Sunday in two churches.

The two men, aged respectively 66 and 67 years, who were operated in 1912 are able to make speeches to large assemblies with a comparatively clear voice.

So as to get a broader basis of judgment as to the results of thyrotomy in cases of intrinsic cancer of the larynx, I have combined in the following table my own experiences and those of F. Semon, Chiari and St. Clair Thomson. The results are as follows:

TABLE C. RESULTS OF OPERATION BY LARYNGOFISSURE

	Cases	Cure over three years	1 to 3 years	Under 1 year	Recurrence	Death from operation
Semon	24	15	4	1	3	1
Chiari	29	11	4	..	11	3
Schmiegelow	33	11	7	..	10	5
St. Clair Thomson	10	7	2[1]		1	..
	96	44	17	1	25	9

[1] Secondary operation for removal of larynx; alive five years later.

You will see from this table that of 96 operated patients 52 (63½ per cent) were cured for more than one year after the operation.

TABLE D

Table of eighteen cases of intrinsic cancer of the larynx, thyrotomized without recurrence.

Age	Sex	Date of operation	Time of observation	Annotations
62	M.	1892	18 yrs.	Died 1910 of cancer rectum. Larynx free.
28	M.	1900	14 yrs.	Alive, no recurrence
50	M.	1904	10 yrs.	Alive, no recurrence.
69	F.	1904	10 yrs.	Alive, no recurrence.
71	M.	1905	9 yrs.	Alive, no recurrence.
55	M.	1896	8 yrs.	Died of cancer of stomach; no recurrence in larynx.
61	M.	1905	8 yrs.	Alive.[1]
56	M.	1900	5 yrs.	Alive, no recurrence.
47	M.	1905	4 yrs.	Died of tuberculosis 1909. Larynx free.
63	M.	1910	4 yrs.	Alive, no recurrence.
44	M.	1896	3 yrs.	Lost sight of.
55	F.	1911	3 yrs.	Alive, no recurrence.
38	M.	1911	3 yrs.	Alive, no recurrence.
66	M.	1911	2½ yrs.	No recurrence, died of some other disease.
58	M.	1912	2 yrs.	Alive, no recurrence.
67	M.	1912	2 yrs.	Alive, no recurrence.
66	M.	1912	2 yrs.	Alive, no recurrence.
74	M.	1912	2 yrs.	Alive, no recurrence.

[1] Seven years after the operation cancer recurred in the larynx, probably new infection.

TYPHOID PERFORATION[1]

By GEORGE E. ARMSTRONG, M. D., Montreal, Quebec

IN the two provinces of Quebec and Ontario in Canada there were, during the five years 1908 to 1912 inclusive, 6,011 deaths from typhoid fever, an average of 1,202 deaths per annum.

In the province of Alberta during the five years 1909 to 1913, inclusive, there were 852 deaths from typhoid fever, an average of 170 per annum.

In the United States of America during the four years 1909 to 1912, inclusive, there were 45,833 deaths from typhoid fever, an average of 11,458 deaths per annum. The average death rate was a little over 20 per 100,000 of population.

The responsibility for this enormous waste of human lives cannot be laid at the door of the medical profession. It is a reflection upon the humanitarianism and business acumen of the laity in these countries. Those who succumb to typhoid are among the most promising in the country. The greatest susceptibility is from fifteen to twenty-five years of age. It has again and again been proved to a demonstration that pure water and efficient drainage prevent typhoid. Typhoid can be arrested by an act of Parliament and by municipal legislation. Regarded as a purely economic question, the money spent in removing the cause of typhoid would earn larger dividends than if invested in the best bonds in the world. Why should not municipalities, towns, and cities be made as responsible financially for the loss of time and loss of life from a preventable disease like typhoid as are the transportation companies by land and water made responsible for preventable accidents.

Typhoid is still with us, however, and it is still attended by a mortality from several complications, 75 per cent of which are surgical. It is to one of the most important of the latter that I would ask your attention. One cannot approach the subject of surgical complications of typhoid without an appreciation of the influence of W. W. Keen, who brought this subject so clearly and forcibly before the profession in his book published in 1898.

The incidence of perforation varies in different years and in different epidemics. In Germany, perforation is less common than in America. Recent figures embracing 9,713 cases collected in England, Canada, and the United States show that more than one-third of the deaths from typhoid are due to perforation. At the Johns Hopkins Hospital there were 43 perforations in 1,500 cases, or 1 in 35. In the Pennsylvania Hospital there were 50 perforations in 1,948 cases, or 1 in 39. In the Royal Victoria Hospital, Montreal, there were 83 intestinal perforations in 2,917 cases, or 1 in 35, and two perforations of the gall-bladder. In the Montreal General Hospital there were 110 perforations in 2,494 cases, or 1 in 22½ cases. In the Royal Victoria and Montreal General hospitals it is sometimes quite impossible to admit all the cases of typhoid that apply. Only the severer cases are taken in. Again, quite a number of cases are admitted after perforation has occurred.

In 15,224 collected cases there were 544 perforations, or about 1 in 31½.

Statistics show perforation to be more common in men than in women. The reason is not obvious. Perforation in children is rarer than in adults.

Pathogenesis. Chomel remarks that "the accident is sometimes the result of ulceration, sometimes of a true eschar, and sometimes it is produced by the distention of the intestine, causing the rupture of the tissue weakened by disease." In a specimen in the McGill Museum there are 10 perforations in the ascending colon and sigmoid, probably from distention. I have usually found the perforation near the base of a generally well-defined ulcer. In size it varies from a very small pin-point hole to an opening the size of a lead pencil. Only rarely is it larger. It is always situated almost directly opposite the mesenteric attachment.

While it is true that the perforation may

[1] Read before the Clinical Congress of Surgeons of North America, London, July 27, 1914.

occur at any point in the stomach, in the small or large intestine, or in the appendix vermiformis, yet, fortunately for the patient and the surgeon, it is found somewhere in the terminal two feet of the ileum in an overwhelming majority of cases.

Prognosis. That a typhoid perforation not closed by the surgeon is always a fatal complication is, as a rule, a true statement. The only exceptions are those in which a perforation of the large bowel occurs between the layers of its mesenteric attachment. When this occurs an abscess develops, extraperitoneally, which may subsequently be opened. In the single case in my series in which this occurred, the fistula gradually healed. It is probable that all cases in which a perforation of the small intestine occurs into the peritoneal cavity prove fatal, unless recognized and the opening closed. The duration of life after perforation in 134 cases collected by Fitz was as follows:

Died on the first day	37.3 per cent
Died on the second day	29.5 per cent
Died in the first week	83.4 per cent
Died in the second week	9 cases
Died in the third week	4 cases
Died in thirty days	1 case
Died in thirty-eight days	1 case

Diagnosis. It is easy to establish the fact that a considerable percentage of the mortality in typhoid is due to perforation of the intestine, and also that a goodly number of these cases may be saved by early recognition and closure of the lesion. The great difficulty is the diagnosis. To get the best results the accident must be recognized early and appropriate treatment instituted promptly. Here is the great difficulty: the question of early diagnosis. Some of our standard textbooks are misleading in their remarks on the diagnosis of typhoid perforation. If it will not be considered too presumptuous for a Colonial to criticize writers in the great educational centers of Great Britain, I would like to say that when a recent edition of Choyce's Surgery says that the symptoms suggesting perforation are the sudden onset of acute pain referred to the umbilicus, or to the right lower half of the abdomen, with muscular rigidity and tenderness on pressure, most marked in the right lower quadrant of the abdomen; and that there is nausea and vomiting and other symptoms of acute infection; and when Howard in his Practice of Surgery, issued this year, says the symptoms of typhoid perforation are sudden, acute abdominal pain, with collapse and fall in the temperature,—they fail to appreciate the difficulties that surround the question of the diagnosis of typhoid perforation. The occurrence of perforation is but seldom indicated by such well-marked, striking symptoms. Furthermore, a fatal peritonitis may develop in typhoid without any perforation discoverable at autopsy, as reported in the Munich autopsies and in various medical journals.

The first indication that a perforation has occurred is usually pain. It was present in 75 per cent of this series of 83 cases and absent in 25 per cent. Seventy-five per cent of them had either sudden crampy pain or sudden persistent pain in the following regions (mentioned in order of frequency): generalized; right lower quadrant; umbilical zone; left lower quadrant; epigastrium; and left hyperchondrium. In 25 per cent of these cases the pain was generalized or in the right or left lower quadrants. Often the pain will not be severe enough to impress upon the nurse the need of sending for the doctor unless she has been specially trained in a typhoid ward. An important point in the training of a typhoid nurse is to teach her to send for the interne whenever a typhoid patient complains of abdominal pain.

In 25 per cent of cases not having pain at onset, the following conditions were found:

In 11 per cent toxæmia obscured all signs.
In 4 per cent the condition was obscured by severe concurrent hæmorrhage.
4 per cent were not diagnosed.
1 per cent had chills.
2 per cent had rigidity.
4 per cent had vomiting.

In regard to time, 62 per cent occurred at night and 38 per cent in the daytime. Four per cent of the cases had definite profuse sweats immediately after the perforation.

The symptom that I would place second, because of its constancy and significance, is change of expression. The change of appearance in a majority of the cases was quite evi-

dent. Sixty-five per cent showed a very definite alteration, 28 per cent a gradual change, and 7 per cent no change. This change in appearance was manifested in a picture of suffering from pain, a sudden pallor, a change from a feeling of comfort to that of distress, a restlessness, cardiac failure, vomiting, painful defecation, loss of rallying power after hæmorrhage, a chill, profuse sweat, general *malaise*, an unaccountable change in general condition for the worse, or, sometimes, a feeling among those in attendance that something had happened that they could not account for.

Tenderness was present in some degree in 88 per cent of the cases and absent in 12 per cent of the cases.

In 50 per cent of the cases it was generalized.
In 20 per cent of the cases it was limited to the lower abdomen.
In 16 per cent of the cases it was limited to the right lower quadrant.
In 9 per cent of the cases it was limited to the left lower quadrant.
In 2 per cent of the cases it was limited to the right upper quadrant.
In 1 per cent of the cases it was limited to the left upper quadrant.
In 1 per cent of the cases it was limited to the upper abdomen.
In 1 per cent of the cases it was limited to the umbilical zone.

As for time of appearance,—

In 50 per cent of the cases it came with pain at the onset.
In 20 per cent of the cases it came within the first hour.
In 16 per cent of the cases it came within the second hour.
In 5 per cent of the cases it came within the fourth hour.
In 2 per cent of the cases it came within the eighth hour.
In 2 per cent of the cases it came within the tenth hour.
In 2 per cent of the cases it came within the twelfth hour.
In 1 per cent of the cases it came within the twenty-fourth hour.

In some cases tenderness is definite from pushing forward the anterior wall of the rectum with the examining finger.

RIGIDITY IN TYPHOID PERFORATION

85 per cent of the cases showed distinct rigidity.
15 per cent of the cases did not.

Of this 85 per cent showing rigidity,—

44 per cent showed it from onset of trouble.
22 per cent showed it within the first hour.
8 per cent showed it within the second hour.
4 per cent showed it within the third hour.
6 per cent showed it within the fourth hour.
6 per cent showed it within the sixth hour.
8 per cent showed it within the twenty-fourth hour.
2 per cent showed it within the seventy-second hour.

Location:

39 per cent showed generalized rigidity.
22 per cent showed rigidity of the right lower quadrant.
22 per cent showed rigidity of lower half of abdomen.
8 per cent showed rigidity of right upper abdomen.
5 per cent showed rigidity of left upper abdomen.
4 per cent showed rigidity of left lower abdomen.

In a very few instances the term "resistance" would more correctly designate the condition present.

Little or no value can be attached to the absence of liver dullness. If the area of liver dullness has been noted from day to day and then suddenly disappears in association with abdominal pain, it is significant. It is valueless in a distended abdomen. It was obliterated in 45 per cent; not changed in 16 per cent; and not mentioned in 39 per cent.

The fall in temperature so often spoken of rarely occurred. Occasionally there was a fall of one or two degrees in six or eight hours, but only in a few cases did any spectacular drop, such as from 103° to normal, take place. In one case the temperature rose from normal to 104° in two hours.

The pulse changes were always clear. A rapid change from slow and good volume to rapid and small often occurred. In 95 per cent of the cases the pulse quickened. Of the change in blood-pressure I cannot speak.

Those who have seen many typhoid perforations will appreciate Fitz's statement that perforation of the intestine in typhoid fever may take place without any suggestive symptoms, and that suggestive — even so-called characteristic — symptoms may occur without any perforation having taken place.

In the textbook perforations, diagnosis is easy; but if we are to save a large percentage of these unfortunate patients, we must detect the accident in its most insidious form.

Again, it is not necessarily a reflection on diagnostic skill and sound judgment when the abdomen is opened after careful consideration of the symptoms present by two or three clinicians and no perforation is found. It would seem that this may happen occasionally if a conscientious attempt is made to recognize perforation as soon as it occurs. One case is on record in which the abdomen was opened twice in the same patient without finding any perforation. The same abdomen was later

opened a third time, the perforation found, and the patient's life saved. We cannot always afford to wait in these cases until the diagnosis is absolutely definite and assured.

What symptoms call for immediate abdominal incision; or rather, what are the minimum of signs that may demand surgical intervention? Pain, persistent; definite change for the worse in the expression of the patient; tenderness, either abdominal or rectal; rounding-up of the abdomen; and increased resistance to pressure. If these symptoms are present, even if the temperature and pulse are not decidedly altered, nor vomiting present, the likelihood of a perforation is very great.

Local anæsthesia has very materially altered our attitude toward early operations. It is no longer necessary to administer a general anæsthetic. The abdomen can be quite well opened under local anæsthesia without causing the patient any pain whatever. The closing of a typhoid perforation is one of the simplest operations in surgery: one that can quite well be performed by anyone capable of carrying out a perfect surgical technique. A one-per-cent solution of novocaine with the addition of two drops of adrenalin to the dram is thoroughly satisfactory and may be used freely. Inject first the skin and subcutaneous tissue, and then, with a needle one inch long, penetrate the deeper muscular layers along the line of incision. Either a gridiron incision or one along the outer border of the right rectus answers admirably. The perforation is nearly always found in the terminal twelve or twenty-four inches of the ileum. It is very easily found. A couple of through-and-through sutures usually suffice to close the opening, and then one or two rows of fine Lembert sutures complete the operation on the intestine. One should always look for a second or possibly a third perforation. These are seldom found, but not uncommonly some of the ulcers in the neighboring portion of the ileum will present a very thin, necrotic-looking base. It is a good practice to infold such with a single row of Lembert sutures as a precaution against further perforation occurring after the addomen is closed. Resection of an ulcerated portion of intestine in typhoid is rarely indicated and should be reserved for the skilled operator and for unusually threatening conditions.

When the abdomen is opened, perforation is generally made clear by the presence of fluid or lymph, or by the escape of a little gas. Should none of these evidences be observed, do not close the abdomen without examining at least the terminal two feet of the ileum. It may be that a small pin-head perforation is temporarily closed by a tag of omentum. I have found this condition present in three of my cases. Of course, such cases give a most favorable prognosis.

The percentage of recoveries is gradually increasing. Von Layden, in 1884, suggested that the only rational way of treating perforations of the stomach and intestines was surgical. In the same year Miculicz closed a typhoid perforation. The patient, a man 40 years of age, recovered. Fourteen years later, Keen collected 83 cases with a recovery percentage of 19.36. In the Royal Victoria and Montreal General hospitals, 140 perforations have been closed and 38 have recovered, or 27.14 per cent. These figures include the work of all the surgeons attached to the hospitals. The figures are not large, but I think they represent 38 lives saved. The other cases of perforation were not operated upon, chiefly for three reasons; viz., not diagnosed; desperate conditions that offered no chance of success; and refusal of patients, parents, or guardian to allow operation.

It is sometimes very discouraging: my first six cases died, and then I was about ready to give it up. I succeeded in saving my seventh case, and from that time recoveries have occurred more and more frequently. From January, 1909, to June, 1914, I closed 22 typhoid perforations, and 11 recovered, or 50 per cent. An important point is to let the house staff feel that it is a reflection on their professional attainments to overlook a perforation. When once they really appreciate that fact, cases are sent to the operating-room promptly.

THE SUTURE OF THE LEVATOR ANI MUSCLE IN PERINEORRHAPHY OPERATIONS[1]

By HENRY JELLETT, M. D., F. R. C. P. I., Dublin, Ireland

THE selection of a subject which is suitable for discussion before this Congress is a matter of some difficulty, since matters which are of the highest interest and importance to the gynecological surgeon are not so necessarily to the general surgeon. At the same time, it is more likely that a specialist will be of interest to his hearers if he deals with a subject which for the moment is of interest to himself, and so I have selected an essentially gynecological subject.

There are other reasons why I have selected this particular gynecological subject. In the first place, although it is a generally accepted fact that the support furnished by the levator ani muscle, either with or without its investing fascia, is essential to the pelvic organs, none of the older methods of perineorrhaphy provides a means of such suture. In the second place, it is surprising how many of the present generation of gynecologists are content to continue to practice these operations, because, and this is my third reason for my choice of subject, they consider, and in fact they are directly told that suture of the muscle, however essential it may be, is a difficult operation, and one not devoid of danger. I do not think that I need spend much time in defending my first reason. Lawson Tait's, Martin's, Hegar's, and Kelly's original operations all neglect to take the levator ani muscle into consideration. It is true that occasionally they may result in causing its suture, but this only occurs when the muscle is not far retracted, while when it is retracted, and when its suture is more imperative, they fail. As to my second reason, any gynecologist present can say whether or not it is right, as well as I, and he can say whether my third reason is not also right, and whether the omission to suture the muscle is not the result of the idea that such suture is difficult.

Döderlein and Krönig, in the latest edition of their work on gynecological operations, and Martin of Bumm's Clinic, in an article on the suture of the levator ani muscle and fascia, are largely responsible for perpetuating this idea. They, however, are apparently strong advocates of suture, and it seems a pity that their writings should rather tend to complicate the operation, and so to prevent its universal adoption.

I have practiced systematic suture of the levator ani muscle for the past six or seven years, and I think I may say that I have sutured the muscle in every case in which I have performed perineorrhaphy during this period except where the muscle was absent or atrophied, but when I stated this fact at a discussion on the subject, I was told that I never sutured it. The reasons given for this statement were first, that Krönig showed how easy it was to mistake a more superficial muscle for the levator ani, and secondly, that Martin said that suture of the levator ani was a difficult operation involving an extensive dissection, whereas my operation was a simple and easy one. It is just because it is simple and easy that I take up the time of the Congress with this paper, in which I desire to show, first, that there are no anatomical difficulties in the way of muscle suture, and secondly that there are no practical difficulties.

The structures which are involved in a perineorrhaphy operation from without inwards are as follows:

1. Skin.
2. Superficial fascia.
3. The constrictor vaginæ muscles, and the superficial transversus perinei muscle.
4. The deep transversus perinei muscle.
5. The levator ani muscle.
6. The vaginal mucous membrane.

We may at once dismiss a number of these structures from consideration because their suture is a part of any perineorrhaphy operation that has ever been devised. These are the skin and superficial fascia, the constrictor vaginæ and superficial transversus perinei

[1] Read before the Clinical Congress of Surgeons of North America, London, July 27, 1914.

muscle, and the vaginal mucous membrane. This leaves two muscles for consideration—the deep transversus perinei and the levator ani. The deep transversus perinei muscle rises from the neighborhood of the point of union of the pubic and ischial rami. As it approaches the middle line, it spreads out. A few of the most anterior fibers pass to the anterior wall of the vagina, and lie behind the urethra. The remaining fibers pass behind the vagina to the central point of the perineum. (Thompson.) A great deal of importance has been attached to this muscle by Krönig, who apparently considers it is a structure which is sufficiently long both to afford support in cases of slight prolapse, and to be mistaken for the levator ani. In his description of perineorrhaphy as performed in cases of slight prolapse, he says that after the initial incision the fibers of the deep transversus can be seen, and their course demonstrated by traction. . . . They lie over the puborectal part of the levator muscle, and have often been mistaken for the latter. "To prevent this mistake the diverging muscle-bundles should be followed to the sides, the deep transversus perinei passes towards the ischial tuberosity, while the levator ani passes forwards towards the pubis." He then goes on to show how this muscle can be sutured.

There are two points raised here with which I must deal at once. The first is that Krönig regards the deep transversus perinei as a structure which can not only be easily found, but which is strong enough to be used to reconstitute the pelvic floor. I should hesitate to say in the face of so eminent an authority that I did not regard either of these statements as correct, even though anatomists and one's own personal experience showed that they are incorrect, was it not that on an earlier page of the same article, Krönig himself places the importance of the deep transversus perinei before us in a true light. Here Krönig definitely states that the deep transversus perinei in nulliparæ is as thick as the little finger, while in multiparæ, and those with poorly developed muscles, it is reduced to mere strands of muscle fiber. It is thus apparently possible that when one comes to perform a perineorrhaphy in the muscular nullipara, one may be able to find and to derive help from the deep transversus perinei!

My second point concerns the anatomy of the muscle, and that there is something radical ly wrong in Krönig's statements about it is shown by comparing his anatomical drawing of the deep transversus perinei with his drawing of the same muscle as exposed during operation. It is difficult to conceive how a muscle possessing the anatomical relations shown in the first drawing could come into the position in which it is seen in the others. As I have said I hesitate to express an opinion contrary to such an eminent authority, but still I cannot help pointing out that I think the fibers which in his drawings of perineorrhaphy purport to represent the deep transversus perinei, really represent some bundles which have been accidentally isolated from the lower and inner edge of the levator ani. Martin puts the case very well when he says, "It is anatomically scarcely possible that Krönig could see the deep transversus passing out from the pubis to the walls of the vagina, when operating on cases with marked atrophy of the muscles." I think then that Krönig's drawings lay a quite unnecessary and a most perplexing stress on the possibility of confusing the two muscles.

The part of the levator ani with which the gynecologist is concerned rises from the back of the body of the pubis, along an oblique line which extends from the lowest limit of the symphysis upwards and outwards to the obturator canal, and also from the obturator fascia for a limited extent. (Thompson.) It passes backwards at the side of the vagina, about half an inch above the hymen, and then similarly at the side of the rectum to be inserted mainly into a median raphé between the anus and the tip of the coccyx. It has also apparently a slight insertion into the vaginal and rectal walls at the point at which it crosses the latter, and it sends a few fibers to meet those of its fellow of the opposite side in the central point of the perineum. It has not, however, any considerable insertion into the perineum,and the union of its fibers which are produced in

this region by operation is purely artificial, and in no way a reproduction of the condition of affairs existing before laceration occurred. If the finger is passed high into the vagina of a nullipara, and then drawn down along one lateral wall exerting a slight outward pressure, it comes to rest on the upper surface of the muscle, the extent and relations of which can be readily ascertained. It will also be obvious that the main masses of the muscle pass backwards at each side of the perineal body with a distinct separation between them. If a similar examination is made in a case of fairly extensive perineal laceration, the lateral masses of the muscle will still be felt, but the gap between them will be greatly increased, in consequence of their outward retraction. Further, if a similar examination is made in the case a patient in whom suture of the muscle has been carried out, the upper border of the lateral masses will be obvious, and so will the fact that they actually meet one another in the middle line throughout the whole anteroposterior depth of the perineum. Lastly, if the muscle is exposed from below, and if it is caught in a forceps and drawn down, the finger in the vagina readily proves that the forceps is holding the muscle which forms the pelvic floor and no other. For this reason I have no hesitation in saying that it is impossible for any one who has become at all familiar with the details of the operation to mistake the muscle for any other structure in the pelvic floor.

Just as the possibility of mistaking a practically non-existant structure for the levator ani has been exaggerated, so has the difficulty of the operation and the extent of the dissection required. I cannot understand this latter exaggeration, but, to show that it exists, I quote a sentence from an article by Martin of Bumm's Clinic, in which he describes an operation that appears to have very few points of difference from the one I habitually practice. Martin writes: "If the fibers of the levator ani are to be brought into view, the connection between the pelvic fascia and the superficial diaphragmatic fascia must be divided. This, however, means a very deep dissection, and causes hæmorrhage if a broad strip of the puborectalis is laid bare, because one is working in the neighborhood of the rectovaginal venous plexus. When the muscle is approximated, the needle frequently pierces this plexus, and so causes emboli as Bumm has described."

I have criticized adversely from the standpoint of my own experiences both Krönig's and Martin's efforts to attach difficulty and danger to the routine suture of the levator ani. There is, however, one disadvantage of a slight character to which they both allude, and which I think requires attention. I refer to the fact that the exposure of the muscle and its separate suture leads to the formation of dead spaces between the vaginal mucous membrane and the upper surface of the muscle. If these spaces are allowed to remain in a condition in which blood can accumulate in them, infection of the clot from the rectum is very likely to occur, and to convert the hæmatoma into an abscess. There is, however, a very simple and essential method which I shall presently describe, of obliterating such spaces, thereby preventing the accumulation of blood in them.

Before describing the operation which I have evolved, and which I habitually practice, I would like to say that I do not claim anything original for it, and that so far as I can see, identical principles of operation must have been adopted by many others. It is only because so many gynecologists seem to consider that routine muscle suture in the course of a perineorrhaphy is difficult and hesitate to perform it on this account, that I describe my own technique which I have followed practically unchanged for the last six years. I cannot give the total number of cases on which my assistants or myself have operated, but during the last three and a half years, 346 perineorrhaphies for chronic laceration have been performed at the Rotunda Hospital, in practically every one of which the levator ani has been sutured. In an occasional case, union has failed to occur, in an occasional case — particularly in the early ones — a hæmatoma has formed, but there has never been a death, or even a patient whose condition gave rise to anxiety owing to the occurrence of emboli from punctured venous plexuses.

I should also like to say, in case the slides of the operation appear familiar to some of you, that the drawings from which they were made were made just two and a half years ago for me from my operations, and that I take no responsibility for their resemblance to any other illustrations which have been drawn and have appeared since. Within the last two months I have had certain anatomical details in them slightly altered, as the levator muscle was placed at too superficial a level.

The essential features of the operation are as follows:

1. The careful dissection of the necessary amount of vaginal mucous membrane from the rectum.

2. The exposure and suture of the separated levator ani muscles.

3. The careful approximation of the cut edges of the vaginal mucous membrane, in such a manner as to leave no projection or redundancy.

The operation is carried out as follows: The extent of the perineal tear is carefully determined, and its anterior edges are marked out by bullet forceps. A third bullet forceps is applied to the perineal skin just behind the posterior edge of the tear. The position of the separated edges of the levator ani is by palpation through the mucous membrane of the vagina. An incision is then made from side to side along the line of junction of the skin and the vaginal mucous membrane. This incision cuts through the skin and any underlying scar tissue. A flap of vaginal wall is then dissected up off the underlying rectum. At its lowest part it is firmly held to the rectum and the sphincter ani by cicatricial bands, the result of the old cicatricial healing. As soon, however, as these have been cut through, the separation of the remainder of the flap by blunt dissection is an easy matter. The easiest method of dividing these bands with the scissors so as to avoid injuring the rectal wall is shown. When the dissection of the flap is complete, a triangular space is exposed, which is bounded laterally below by the remains of the superficial vaginal and perineal muscles, and at a deeper level by the pubococcygeal fibers of the levator ani muscle while its floor is formed by the rectum. It is then an easy matter to catch the edges of the levator ani with clip forceps or dissecting forceps, and to draw them downward and inward until they meet in the middle line. If the separation and atrophy of the muscle is marked, then it may not be possible to draw the edges down sufficiently, but in the great majority of cases, they can be brought into view as shown. Three or four interrupted sutures of catgut are then passed through them from side to side so that when tied they will approximate them in the middle line, for the present, however, they are left untied. The next step is to trim the vaginal flap into proper shape, so that, when the operation is complete, there may be no redundancy. The usual line of incision is shown, and the effect of the removal of redundant tissue. The cut edges of the flap are then brought together by a continuous catgut suture passed from above downward, and ending at the vulvar orifice. This being done, the catgut sutures in the levator muscles may be tied. The last step consists in the introduction of silkworm gut sutures passed so as to close the skin edges of the perineal wound. These sutures are passed from side to side, and traverse the skin, and the remains of the superficial perineal muscles and also the levator muscle so as to supplement the buried catgut sutures.

Sometimes during this procedure there may be hæmorrhage from the hæmorrhoidal vessels Any bleeding vessel, if of large size, should be caught and tied but, as a rule, the best method of stopping bleeding is by proceeding rapidly with the operation.

I have mentioned the tendency there is to the formation of dead spaces between the vaginal mucous membrane and the upper surface of the levator ani, as a result of the necessary stripping up of the vaginal flap and the separation of the edges of the muscle from the sides of the vagina. The final step of the operation is directed towards the prevention of the accumulation of blood in such spaces, and is, in my opinion, an essential precaution. It consists in the firm plugging of the vagina with iodoform gauze. The

plug must be applied most carefully, so as to avoid injury to the vaginal sutures, and in such a manner that it lies wholly above the muscle with the exception of the end which hangs out through the vulvar opening. It is quite impossible to introduce it satisfactorily by merely pushing it upwards through the narrowed orifice. The reconstituted perineum must be drawn carefully backwards by means of a narrow retractor passed into the vagina, so as to lie above the levator muscle. The retractor which I use for the purpose is known as Doyen's anterior vaginal retractor. Though intended as an anterior retractor, it possesses a blade which is set at just the correct angle to the handle to allow it to pull back the posterior vaginal wall and the muscle in the manner required for the insertion of the plug. By means of it, it is possible to introduce a strip of gauze about three inches wide and some five to six yards in length in such a manner that, while the gauze expands the upper part of the vagina and keeps the posterior vaginal wall in close contact with the sutured muscle, it throws little or no strain on the sutured mucous membrane which lies below it.

I have described this step in detail because I attach very great importance to it, and because it is impossible to carry it out satisfactorily without a suitable appliance such as the retractor I mention.

The advantages of the foregoing operation are its ease and its rapidity. In an ordinary uncomplicated case it can be finished in less than ten minutes, and it very rarely takes more than fifteen minutes. The advantages of positive suture of the levator ani in perineorrhaphy operations are so obvious that they do not require mention but to emphasize them I show four diagrams, which I constructed with fair accuracy from two cases of perineorrhaphy. The first pair of these show the condition of the perineum and the relations of the rectum and the vagina in a patient on whom one or the other of the older perineorrhaphy operations had been performed. The external results was apparently excellent, but on passing the finger into the vagina, the perineum was found to consist of a thin shelf, formed of skin and superficial fascia. A little further examination showed that the lateral masses of the levator ani muscle, well developed but widely separated, lay in the position into which they had retracted as a result of the original laceration. The second pair of diagrams show the same points in a patient in whom the muscle had been sutured and the operation carried out as I have described. The difference in the condition of the perineal body is at once obvious, and further examination showed that the lateral masses of the levator met in the middle line. In fact, the shape of the perineum is practically that found in the nullipara, and the only difference is that the inner muscle edges meet in the middle line instead of merely sending a few fibers into the central tendon of the perineum.

CONCLUSIONS

1. Routine suture of the levator ani is an essential part of perineorrhaphy.

2. Routine suture is always practicable, except when the muscle is wanting owing to atrophy after injury. Such absence is very rare, and, when it occurs, it is impossible to reconstitute the perineum satisfactorily.

3. The exposure and suture of the levator ani is neither difficult nor dangerous.

HYPERTHYROIDISM: PRIMARY AND LATE RESULTS OF OPERATION[1]

By C. H. MAYO, M. D., Rochester, Minnesota

THE term hyperthyroidism is so expressive of a group of symptoms, the symptom-complex of which has been seen and described under various names in all countries, that it is chosen as the title of this study.

Through one hundred and fifty years the condition has been a topic of discussion by Morgagni (1), Flajani (2), Parry (3), Graves (4), Basedow (5), and later, under the term "exophthalmic goiter," by innumerable other observers.

The thyroid is a very necessary gland in the growth and development of body and brain and must also be classified among both the glands of nutrition and the glands of defense. Like all the essential organs and kinetic glands of the body, it has a wide variation of its activity within the limits of health. Probably the secretion of one-sixth of the adult gland is enough to maintain the metabolic balance, which is no more surprising than that one-half of one kidney will maintain urinary balance. A similar condition exists in many other organs of the body.

Many factors exist which control such organs in order that the balance of health may be maintained, yet any or all of them may be temporarily deficient or overactive in their functions; but, unless there be an actual great loss of cells or a markedly hyperplastic condition, they are held in control. In this variation of activity in the normal thyroid, and in the normal changes in activity of its various vesicles, the thyroid sometimes manifests a storage function, retaining for a time its secretion, and depositing colloid substance for this purpose.

This almost brainlike intelligence of the glands, both duct and ductless, shows why so futile is the effort to transplant glands from other animals to the human, with the expectation that the gland will automatically functionate. Especially is this true of the reported cases of the transplantation of glands from animal to man, in which there is always a definite laking of the blood. A temporary benefit may be obtained, however, from the transplantation of the glands of internal secretion through the digestive power of the phagocytes.

That there should be a definite microscopic picture in so definite a disease as hyperthyroidism is to be expected. The only organ that gives such an exclusive picture is the thyroid. The trained pathologist should not only recognize the condition, but also its degree of activity and its stages; that is, whether progressing, regressing, or regenerating.

The coincident pathology of the other essential organs, such as nephritis, fatty degeneration of the liver, myocarditis, and brown atrophy of the heart muscle, while characteristic of toxæmia, would not necessarily come from the toxic thyroid. The enlarged thymus is found in a majority of cases of hyperplastic thyroid, yet is not found in many of the most serious cases.

In the pathologic examination, the whole of the tissue removed must be macroscopically observed, that an unessential small area of hyperplasia or of colloid storage be not chosen as the sole picture of the glandular histology. The changes in so small an amount of tissue may be neutralized by other factors. The pathologic material from our cases has been studied by Wilson. (6) In his most recent paper he presents a comparative study of the thyroids from the three groups of cases which we recognize clinically (Plummer). They are summarized as follows: (*Table 1*)

"1. Practically all cases of clinically true exophthalmic goiter show marked primary hypertrophy and hyperplasia of the parenchyma of the thyroid. Furthermore, the clinical stage of development of the disease is paralleled by the stage of development of the pathologic condition in so sufficiently marked a degree that one may estimate the clinical condition from the pathologic examination with about 80 per cent of accuracy. The degree of severity of the clinical condi-

[1] Read before the Clinical Congress of Surgeons of North America, London, July 28–30, 1914.

TABLE I.—COMPARISON OF PATHOLOGIC GROUPING OF THYROIDS FROM CASES OF TOXIC HYPERPLASTIC, TOXIC NON-HYPERPLASTIC, AND ATOXIC (SIMPLE) GOITER

	Percentage Distribution					Average Age at Operation				
	Exoph. goiter. "Exoph. list," 1911–12. 431 cases	Toxic goiter clinical, Group 2. "Exoph. list," 1910–12. 129 cases	Toxic goiter clinical, Group 1. + "Simple list," 1911–12. 155 cases	Toxic goiter clinical, Group 1. ? "Simple list," 1912. 90 cases	Atoxic (simple) goiters. "Simple list," 1912. 373 cases	Exoph. goiter. "Exoph. list," 1911–12. 431 cases	Toxic goiter clinical, Group 2. "Exoph. list," 1910–12. 129 cases	Toxic goiter clinical, Group 1. + "Simple list," 1911–12. 155 cases	Toxic goiter clinical, Group 1. ? "Simple list," 1912. 90 cases	Atoxic (simple) goiter. "Simple list," 1912. 373 cases
			374 cases					374 cases		
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Years.	Years.	Years.	Years.	Years.
A Early primary parenchymatous hypertrophy and hyperplasia	4.0	....	....	....	....	25.0	....	....	....	....
B Advanced primary parenchymatous hypertrophy and hyperplasia	43.0	....	....	....	....	31.7	....	....	....	....
C Regressing primary parenchymatous hypertrophy and hyperplasia	52.5	....	....	....	....	40.7	....	....	....	....
Average of total parenchymatous hypertrophy and hyperplasia	99.5	....	....	....	0.5	35.9	....	....	....	....
D Secondary regeneration of atrophic parenchyma of "colloid" goiter	....	50	17	9	9.0	....	34.0	32.0	38.0	31.0
E Fœtal adenomas	....	12	7	10	5.0	....	39.0	47.0	39.0	38.0
F Degenerating fœtal adenomas	....	33	14	18	18.0	....	43.0	50.0	48.0	40.0
Average of total fœtal adenomas	....	45	21	28	23.0	....	41.0	48.9	44.7	39.7
G Adult "colloid" adenomas	....	3	21	19	23.0	....	45.0	44.0	43.0	39.0
H Atrophic parenchyma, ("colloid") thyroids, "adenomatoses," etc.	....	2	41	44	44.0	....	52.0	46.0	41.0	37.0
Average of total colloid goiters, adult parenchyma	....	5	62	63	67.0	....	47.5	45.0	41.6	37.5
	Average Duration of Goiter Before Operation					Average Weight of Portion of Gland Removed				
	Years.	Years.	Years.	Years.	Years.	Grams.	Grams.	Grams.	Grams.	Grams.
A Early primary parenchymatous hypertrophy and hyperplasia	0.3	....	....	....	....	38	....	....	....	....
B Advanced primary parenchymatous hypertrophy and hyperplasia	0.9	....	....	....	....	61	....	....	....	....
C Regressing primary parenchymatous hypertrophy and hyperplasia	3.5	....	....	....	....	51	....	....	....	....
Average of total parenchymatous hypertrophy and hyperplasia	2.3	....	....	....	....	55	....	....	....	....
D Secondary regeneration of atrophic parenchyma of "colloid" goiter	....	6.9	15.3	8.0	9.6	....	67.0	100	153	143.0
E Fœtal adenomas	....	4.4	5.8	13.6	12.5	....	68.0	97	139	122.0
F Degenerating fœtal adenomas	....	12.6	22.7	24.2	13.1	....	91.0	186	190	129.0
Average of total fœtal adenomas	....	8.8	18.0	20.5	13.0	....	83.7	162	172	127.5
G Adult "colloid" adenomas	....	17.7	15.2	14.5	14.3	....	139.0	184	206	147.0
H Atrophic parenchyma, ("colloid") thyroids, "adenomatoses," etc.	....	12.0	20.2	16.5	14.5	....	140.0	196	188	164.0
Average of total colloid goiters, adult parenchyma	....	14.0	18.7	16.0	14.4	....	139.0	192	193	159.0

tion is similarly paralleled by the pathologic condition of the gland. The relationship between hypertrophy and hyperplasia of the thyroid and the clinical symptoms of true exophthalmic goiter is remarkably constant."

"2. While mild degrees of hypertrophy and hyperplasia within physiologic limits may be present in the gland, particularly in the young and during pregnancy, yet the absence of this condition in the thyroids of adults coming to operation for toxic-non-exophthalmic and non-toxic goiters is most striking. Without making any allowance for either clinical or pathologic errors of diagnosis, less than one per cent of all cases coming to operation for goiter show any considerable primary hypertrophy and hyperplasia of the parenchyma of the throid except as associated with clinical symptoms of true exophthalmic goiter."

"3. The pathology of atoxic simple goiter is marked essentially by atrophic parenchyma, decreased function, and decreased absorption. The process is a chronic one."

"4. The pathology of toxic-non-hyperplastic goiter of Plummer's (7) Clinical Group 2 (that is, those resembling exophthalmic goiter) is one of increased parenchyma through regenerative processes in atrophic parenchyma or the formation of new parenchyma of the fœtal type with an increase in each instance of secretory activity and of absorption. The process is a chronic one, but sufficiently active to cause the patient to consult a surgeon earlier than do those in Clinical Group 1."

"5. The nearer the cases of Clinical Group 2 (toxic-non-hyperplastic) approach, in age and symptoms, true exophthalmic goiter, the shorter the duration of the period of goiter before operation and the smaller the average weight of the gland at the time of its removal."

"6. The cases of toxic goiter of Clinical Group 1 (that is, those in which the symptoms are of the cardiovascular variety) much more closely resemble cases of simple goiter in their pathology in all respects than do the cases of Clinical Group 2. A larger number of them are of the colloid goiter type; the enlargement of the thyroid has existed for a longer period before operation, and the portion of the gland removed is materially larger than in those cases of Clinical Group 2."

"7. Finally, it may be stated that all the above pathologic evidence points to a constant relative association of increased secretion and increased absorption from the thyroid proportional to the degree of toxicity on the part of the patient. We have as yet no absolute proof that such secretion and absorption is the cause of, rather than coordinate with, the symptoms, but the presented evidence strongly points to that conclusion."

What causes an overactivity of the thyroid? It is possible that the condition may arise from extra demands made upon the gland in its capacity for nutrition or defense in toxic conditions. Possibly in its latent sex relationship such demands may be temporary or long-continued. For a time the excess secretion may be neutralized. When shock is attributed as the cause of the sudden onset of hyperthyroidism, it is often only an evidence that the equilibrium of the nervous system has been upset in the presence of a latent hyperplastic thyroid, thus producing the sudden symptoms which had previously been controlled or neutralized.

Up to July 1, 1914, 6960 operations had been performed for goiter in our clinic. Of these, 3327 were performed upon patients with hyperthyroidism. The greater number of these patients have been seen clinically by Plummer. His observations on the symptoms are as follows:

"The cases were classified clinically as hyperplastic toxic, hyperplastic atoxic, non-hyperplastic toxic, and non-hyperplastic atoxic.

"Patients coming under observation with non-hyperplastic toxic goiter gave a history of having first noted the goiter at the average age of 22 years, and the evidence of intoxication at the average age of 36.5 years. The corresponding ages for hyperplastic goiter were respectively 32 and 32.9 years.

"That non-hyperplastic toxic goiter was noted 10 years earlier in life than hyperplastic toxic goiter, that 14.5 years elapsed between the appearances of non-hyperplastic goiter and

the development of notable toxic symptoms; and that the constitutional symptoms were noted but a few months later than the goiter in the patients affected with hyperplastic thyroid, was alone sufficient to show that we were dealing with at least two distinct pathologic and clinical groups. That one was not the sequence of the other was self-evident.

"We may safely come to the conclusion that exophthalmic goiter is a definite clinical complex always associated with hyperplasia of the thyroid, and that it should be sharply distinguished from the constitutional state that may develop with non-hyperplastic goiter.

"Let us note the parallelism of thyrotoxicosis and alcoholism and assume that there are three toxic elements in the thyroid secretions: one damaging chiefly the nervous system, one the circulatory system, and the other producing exophthalmos. In exophthalmic goiter all three elements are in excess, but the clinical picture is dominated by a nerve toxin although in individual cases the circulatory toxin or element producing exophthalmos may seem to be in excess.

"The intoxications from non-hyperplastic goiter may be divided into two merging groups: (1) A group in which the cardiac toxin predominates, in which the clinical picture closely resembles and in many instances cannot be differentiated from the cardiovascular complex resulting from alcoholic, luetic, septic, and other well-known toxins; (2) a group more closely approaching the picture of Graves' disease and including the cases that have been erroneously so diagnosed by the mass of the profession." (In this group are those cases in which there is degeneration of encapsulated adenomata. While they do not have exophthalmos, in lieu of this they may have the staring and widening of the palpebral fissure. The pulse is irregular in tension and ryhthm. Circulatory changes and muscular weakness are marked. Many of them have been treated for hyperthyroidism and some of them rendered worse by the further degeneration of the gland which has been induced by cytolytic serums.)

"The average lapse of time between the appearance of non-hyperplastic goiter and toxic symptoms is 14.5 years. That the patient comes under observation three years later indicates that the onset is usually insidious. Nervousness, tremor, loss of strength and weight, as a rule, develop slowly, but may appear suddenly long before definite evidence of myocardial damage. The administration of iodine may cause the sudden appearance of those symptoms with myocardial insufficiency much as they might follow the prolonged drinking bout of an old toper who had not previously shown decided evidence of chronic alcoholism. In some cases the clinical aspect, as noted above, closely approaches that of exophthalmic goiter. However, the symptoms are less complex, less definitely associated, and, except for a damaged heart, less intense. There is much evidence to suggest that during the 14.5 years previous to the onset of definite toxic symptoms many of the cases of non-hyperplastic thyroid may be compared to the alcoholic tippler in that if the soil is right they develop arteriosclerosis, in many cases showing the combined picture of thyrotoxicosis and arteriosclerosis.

"The development of a typical syndrome of Graves' disease in a case having a definite history of simple goiter means that a hyperplastic goiter has been superimposed upon the simple type.

"The onset of exophthalmic goiter is, as a rule, relatively acute and the course of the disease fairly definite. The clinical picture early in the history is that of a toxin acting directiy on the more vital organs, more notably on the central nervous and vascular systems. Later it is made more complex by the interaction of those organs whose functions have been directly disturbed by the toxin. The order of onset of the most important symptoms based on the average of our series is as follows: (1) Cerebral stimulation, (2) vasomotor disturbances of the skin, (3) tremor, (4) mental irritability, (5) tachycardia, (6) loss of strength, (7) cardiac insufficiency, (8) exophthalmos, (9) diarrhœa, (10) vomiting, (11) mental depression, (12) jaundice, and (13) death.

"If the average course of the intoxication be represented by a curve, the greatest height is reached during the latter half of the first year, and then suddenly drops to the twelfth month. In many instances it reaches the normal base-line during the next six months. More often it fluctuates with periods of exacerbation for the next two to four years. Secondary symptoms and exophthalmos may remain, but the active course only rarely continues over four years without distinct intermissions. Compare the striking resemblance of the character, order of onset, and course of this train of symptoms with that resulting from the heavy use of alcohol by a susceptible individual over a corresponding period of time. Near the crest of the curve any shock, operation, etc., that treats the patient to another drink may result in tremens or death.

"In the average course, after the first year, the symptoms that may be attributed to long-continued intoxication rather than to a high degree of acute intoxication—that is, those from the more chronic types of heart, liver, and degeneration of the kidney—enter into the clinical picture. In attempting to construct a composite curve, we find that the curves of those symptoms that we can readily attribute to a high degree of immediate intoxication from the thyroid gradually drop, while the curves for those findings attributable to a long-continued intoxication of a lower degree gradually rise."

The various types of goiter should be treated both medically and surgically. Many goiters of the simple and mild exophthalmic type undoubtedly regress spontaneously, although various forms of medical treatment may hasten the recovery and restoration of the gland to an apparently normal condition in many instances, especially in the early stages of simple goiter.

Exophthalmic goiter is essentially a disease of a chronic character, presenting exacerbations and ameliorations of symptoms extending over a period of months or several years. After the first year the gland often undergoes a regression.

While this disease is amenable to surgical treatment by the removal of a large amount of the hypersecreting gland, it is by no means urgent surgery; and all patients during periods of exacerbation should be considered as medical cases. Surgery is indicated in the up-wave of improvement. The majority of these cases can withstand thyroidectomy at the time they are seen by the surgeon. Extreme conditions, especially dilatation of the heart, may require medical preparation, and the operative interference following in cases resistant to treatment should be confined to injections of boiling water into the gland, after Porter's (8) plan, to hasten improvement. In most of the severe cases, a ligation is made first of the left upper pole only. Should the reaction following this be severe, the ligation of the right upper pole is indicated a week later, and thyroidectomy reserved until four months have elapsed, by which time these patients have made an average gain of twenty-two pounds, with great general improvement. However, if the reaction following the left ligation is not unduly severe, a partial thyroidectomy may be made at the second operation, the week following.

Ligation. The ligation of vessels as an operative procedure was performed in the early part of the nineteenth century and later revived by Wölfler. The ligation of the *superior thyroid* arteries is made through a transverse incision over the center of the thyroid cartilage. The incision is made through the skin and platysma muscles. Blunt dissection with spreading probe-pointed scissors exposes the inner border of the sternomastoid muscle, which is drawn outward. The anterior belly of the omohyoid muscle is next exposed, elevated, and drawn inward, which brings into view the upper pole of the thyroid with its vessels. A permanent ligature is passed around these viens and arteries, close to the gland or even including its tip. This prevents reversal of circulation by vessel-anastomosis, which occurs from high ligation of the artery. Injury to the nerve is not feared, as here the incision is made between the superior and inferior laryngeal nerves and the gland is easily approached. No drainage is necessary. According to the purpose of the operation, and to the condition

of the patient, one or both sides may be ligated at the same time.

Ligation of the *inferior thyroid* artery is made through a lower transverse incision between the insertions of the sternomastoid and requires elevation of the lobe of the thyroid and exposure of the vessel at the point the ligature is applied, so that nerve-tissue may not be included. This operation is usually done only for those patients suffering from a severe relapse after a partial thyroidectomy. Operating thus in stages may be advisable in certain cases, especially of exophthalmic goiter; for example, the upper left pole may be ligated under novocaine. Should severe reaction ensue, a few days later the right ligation is made, from which there is less reaction. If the primary operation has been made without marked bad effect upon the patient, the secondary operation of thyroidectomy may be done in about a week. In the cases in which only double ligation has been done at an earlier period, the larger part of the gland may be removed at the end of four months. By this time the patients who have been under weight will have gained an average of twenty-two pounds, and the thyroidectomy can be made with safety.

Sympathectomy. The Jaboulay operation is a cervical sympathectomy of the superior and sometimes of the middle ganglia and is employed in those cases in which the exophthalmos is marked, the nervous symptoms active, and the gland small. In such cases the superior thyroid vessels are often ligated in the same incision. This operation can be done with novocaine as a local anæsthetic, but is preferably made with a general or combined anæsthestic. Incisions are made in the lines of the natural creases in the neck opposite the bifurcation of the carotid. The sternomastoid is drawn outward and a blunt dissection is made down to the jugular and carotid veins, which are then drawn inward. The posterior sheath of fascia inclosing these vessels is opened that the vagus nerve may be kept under observation, since this nerve is bulbous above this point and may be confused with the sympathetic.

Under normal conditions the sympathetic ganglion is one-eighth to one-fourth of an inch wide. Many branches lead from it on either side. The connecting branches are divided, the upper part of the ganglion torn off or cut, and the lower portions of the nerve cut or torn off at the middle ganglion unless the middle ganglion is also removed.

Thyroidectomy. The angular or bayonet incision is made for the removal of high-lying goiters which have developed in the upper pole of the gland. The best general exposure of the thyroid is through a low collar incision, commonly known as the Kocher incision, which includes the skin and platysma and extends laterally to the external jugulars. The skin with platysma is dissected upward, and also downward, uncovering the sternohyoid muscles. These are separated by a vertical incision which includes the fibrous capsule over the gland. Lateral traction, separating the two sternohyoid and also the sternothyroid beneath them, exposes the thyroid gland sufficiently and gives enough room for the removal of small goiters. However, in large and exophthalmic goiters it is necessary to divide the sternohyoid muscle in the upper part of the field over the thyroid cartilage. This is important, since, when reunited, it preserves the nerve supply and breaks the line of closure of skin and muscle, preventing a muscle-drawn scar which moves with deglutition. The sternohyoid can usually be retracted, but should be divided if it limits the working field. Many of the troubles and accidents in the surgery of goiter would be avoided if the preliminary exposure of the thyroid were adequate before proceeding with the gland itself.

The lateral veins are caught and divided between clamps. The gland is gently elevated with the hand, and, under slight tension, the vessels at the upper pole are caught and divided between forceps. This is repeated on the anastomosing vessels close to the isthmus. The vessels at the lower pole are treated in the same manner, the gland being held in the hands of an assistant, who keeps up continual traction, gradually elevating and turning with the isthmus across the trachea, where the separation is made along the opposite lateral lobe. Few forceps

are required in simple goiters, while the hyperplastic types require many. However, in the excision of an exophthalmic goiter one must keep close to the gland; and it is well to divide the capsule along the lateral border, which is caught in many clamps, and the gland more carefully enucleated, saving this capsule, which effectually protects the recurrent laryngeal nerves and also the parathyroids.

The anæsthetic of choice in most cases is ether. Complicated cases, however, may be best carried through the operation by the local use of 0.5 per cent novocaine solution, with the addition of a little adrenalin. Occasionally the combined use of a local with a general anæsthetic is advisable, a method which Crile has done much to popularize; the local anæsthetic relieving the pain necessitates less of the general anæsthetic to secure sleep.

In severe forms of Graves' disease the use of 1/200 grain of scopolamine with 1/6 grain of morphine one hour previous to operation is often a distinct advantage. Some patients seem to have an idiosyncrasy to the drug, and in such cases the operation must be postponed twenty-four hours to permit elimination. In all cases in which ether is used as the general anæsthetic, 1/100 grain of atropine should be given one-half hour before operation to maintain a dry trachea and pharynx during the operative procedure.

Mortality. The great lowering of mortality following operation for exophthalmic goiter is due less to trivial details of technique than to the better judgment in the preparation of patients, the selection of a time, type, and extent of operation, and its division into stages, with varying intervals of rest. The high mortality of the past is no longer a determining factor against the surgical treatment. As many as 278 consecutive operations have been made on the thyroid between deaths occurring from the operation. The average operative mortality at present probably varies from one to three per cent. Relapse of some degree occurs in a small percentage of cases through the removal of too small an amount of the thyroid. Such cases should be reoperated.

The following is the report of a few interesting cases ranging from one to several years since operation.

CASE 1. 95443. O. E. L. Male, married, age 29. Examined November 13, 1913. *History:* Onset of symptoms five months prior to examination; i. e., nervousness, tachycardia, exophthalmos, and loss of strength. Goiter had been noted for fifteen months. Six weeks prior to examination, tremor, dyspnœa, insomnia, and sweating developed. Symptoms steadily increasing. Loss of weight twelve pounds. *Examination:* Marked evidence of all the preceding symptoms; definite exophthalmos; bruits in superior thyroid vessels; dilated heart; pulse 110. *Operation:* November 20, 1913. Ligation of left superior thyroid vessels followed by thyroidectomy seven days later. February 10, 1914, patient reports great improvement; has gained twenty pounds in weight; pulse 80; exophthalmos less marked; nervousness greatly reduced.

CASE 2. 94464. A. H. T. Male, married, age 41. Examined October 27, 1913. *History:* Acute articular rheumatism five times. Ten months prior to examination the patient became nervous, with tremor, dyspnœa, palpitation, tachycardia, and loss of strength. Eight months later goiter and exophthalmos were noted. *Examination:* Marked exophthalmos; forty pounds loss in weight; bruits in superior thyroid arteries. *Operation:* Thyroidectomy on November 3, 1913. February 10, 1914, patient reports himself cured; a gain of twenty-five pounds in weight; pulse 72; exophthalmos greatly improved; only slight nervousness.

CASE 3. 94372. E. B. Female, single, age 20, height 5 feet 6 inches. Examined October 25, 1913. *History:* Nervousness, tremor, dyspnœa, palpitation, tachycardia, loss of strength, sweating, and prominence of the eyes for one year. Ten months previously there was an attack of vomiting and diarrhœa, following which the patient was in bed for four months and lost fifty pounds in weight. She then improved until one month before examination, when she began vomiting and exhibited evidence of increased intoxication. *Examination:* Definite exophthalmos; marked thrills and bruits in the superior thyroid vessels; pulse 130. *Operation:* On November 3 and 10, 1913, the thyroid vessels were ligated. February 10, 1914, the patient reported steady gain in strength, increase in weight of ten pounds, and general improvement.

CASE 4. 94806. A. B. Female, married, age 26, height 5 feet 8 inches. Examined November 2, 1913. *History:* No children; goiter for six years. All the features of nervousness, tremor, palpitation, tachycardia, loss of strength, diarrhœa, exophthalmos, and extreme intoxication existed during the first year. Since then, symptoms fluctuating but never returning to normal. She was able to do some housework. *Examination:* First degree of exophthalmos, thrills and bruits in both thyroid vessels. The pulse was 150; heart dilated;

she had lost 23 pounds in weight. *Operation:* Thyroidectomy on November 7, 1913. On February 13, 1914, the patient was reported "almost well"; pulse 78; a gain in weight of eleven pounds.

CASE 5. 78726. M. C. P. Female, single, age 20. Examined January 18, 1913. *History:* Five months previous to examination she developed symptoms of goiter; nervousness, dyspnœa, palpitation, tachycardia, vomiting, diarrhœa, insomnia, sweating, and exophthalmos; symptoms steadily progressive. *Examination:* Acute intoxication; definite Stellwag; marked thrills and bruits in the superior thyroid vessels; heart dilated; pulse 120. *Operation:* January 27, 1913, ligation of the left superior thyroid vessels. February 1, 1913, thyroidectomy. February 10, 1914, the patient was reported "cured." There had been a gain of thirty-five pounds in weight; eyes were normal, pulse 85, and very little nervousness.

CASE 6. 77188. L. R. M. Female, married, age 27. Examined December 10, 1912. *History:* No children; always well; goiter for ten years. For the past two years she has noted enlargement of goiter and has developed nervousness, tremor, dyspnœa, palpitation, tachycardia, loss of strength, insomnia, sweating, and exophthalmos; steady increase in severity of symptoms. *Examination:* Pulse 130; definite exophthalmos; thrills and bruits in superior thyroid vessels; cardiac dilatation and other evidences of acute intoxication. *Operation:* On December 17 and 24, 1912, the superior thyroid vessels were ligated. On February 22, 1913, patient returned for thyroidectomy. February 10, 1914, a report of great improvement was obtained; thirty-five pounds gain in weight; pulse 76; eyes nearly normal; able to do customary work.

CASE 7. 76360. W. B. T. Female, married, age 42. Examined November 20, 1912. *History:* One child one year old; goiter developed following childbirth. Symptoms: nervousness, tremor, dyspnœa, palpitation, loss of strength, sweating, and exophthalmos. Acute condition lasted three months; after that slow improvement of symptoms. *Examination:* Definite exophthalmos; thrills and bruits in superior thyroid vessels; slight cardiac dilatation; pulse 116; forty pounds loss in weight. *Operation:* Thyroidectomy, January 8, 1913. February 10, 1914, patient reports great improvement; thirty pounds gain in weight; pulse 80; eyes nearly normal. She is doing her customary work.

CASE 8. 71815. M. H. Female, single, age 47, height 5 feet 2 inches. Examined August 8, 1912. *History:* Fifteen months ago pulse 150, tremor, nervousness, loss of weight, vomited a few times; patient in bed one month. Entire attack lasted three months; very severe. Taught school all last year but did not regain weight or strength entirely; tremor remained. In the past month symptoms returned with loss of weight from 135 to 110 pounds; nervous and weak—not confined to bed but has been up and down. *Examination:* Showed first degree of exophthalmos; pulse 110 to 120; left heart slightly dilated. *Operation:* August 22, 1912, ligation left superior thyroid artery. August 28, 1912, ligation right superior thyroid. May 18, 1914, patient reports herself strong, able to work, not nervous or excitable, and weighing 150 pounds.

CASE 9. A67678. F. P. Female, married, age 37, height 5 feet 2 inches. Examined May 10, 1912. Three children; youngest six months old. *History:* Noticed small lump right side of neck for ten years; no symptoms until three months ago when she developed a rapid heart action, fatigue, nervousness, and loss of weight. One month ago vomited from seven to ten days everything swallowed. Severe diarrhœa for three days one and a half months ago. Goiter has grown very rapidly since February. Average weight 125 pounds; weighed 88 pounds three weeks ago. Irritating cough with expectoration. *Examination:* Showed second degree of exophthalmos, thrills, and bruits in both superior thyroid vessels; pulse 156; present weight 80 pounds. *Operation:* May 22, 1912, ligation of both superior thyroid arteries. May 11, 1914, patient reports herself much improved in general health and strength; tremor almost disappeared; pulse 70 to 80; present weight 127 pounds.

CASE 10. 25098. J. E. K. Female, married, age 28. Examined June 21, 1909. *History:* Three months prior to examination patient developed hyperthyroidism, nervousness, protrusion of eyes, cardiac dilatation; pulse 140; 25 pounds loss in weight. Symptoms repeatedly progressing. *Examination:* Definite exophthalmos; bruits in thyroid vessels. *Operation:* June 24, 1909, thyroidectomy. February 10, 1914, patient reports herself cured; has gained fifty pounds in weight; eyes improved; pulse 84; doing customary work.

CASE 11. 22288. L. K. O. Female, married, age 26. Examined April 8, 1909. *History:* One child, age six years. Six months previous to examination goiter was noted with symptoms of nervousness, tremor, exophthalmos, tachycardia, dyspnœa; steadily progressing. *Examination:* Exophthalmos; marked bruits in superior thyroid vessels; pulse 130; twenty pounds loss in weight. *Operation:* April 14, 1909, ligation. October 4, 1909, thyroidectomy. February 10, 1914, patient greatly improved; twenty pounds gain in weight; pulse 90; doing customary work.

CASE 12. 20797. F. F. K. Male, single, age 40. Examined March 2, 1909. *History:* Exophthalmos developed three years prior to examination. Two years later symptoms appeared of nervousness and cardiac dilatation; twenty pounds loss in weight; goiter not noticed. *Examination:* Pulse 120, definite goiter and marked intoxication. *Operation:* March 6, 1909, thyroidectomy. February 10, 1914, patient is reported as being entirely well and doing more work than usual; pulse normal, eyes improved, gained forty pounds.

CASE 13. 19390. E. J. G. Female, married, age 53. Examined January 23, 1909. *History:*

No children. In 1906 patient developed nervousness, tremor, tachycardia, palpitation, dyspnœa, œdema, diarrhœa, and loss of strength. One year prior to examination exophthalmos appeared six months later goiter. Symptoms severe during first year, fluctuating since then. *Examination:* Marked Stellweg; arrhythmia; pulse about 100. *Operation:* January 23, 1909, thyroidectomy. February 10, 1914, patient greatly improved and doing customary work; pulse 80; eyes improved; gain in weight.

CASE 14. 18484. A. W. B. Female, married, age 20. Examined December 19, 1908. *History:* Marked exophthalmos in 1904. One year later goiter, nervousness, tremor, and dyspnœa; symptoms gradually progressing. *Examination:* Marked exophthalmos; cardiac dilatation; pulse 120; acute intoxication. *Operation:* January 7, 1909, thyroidectomy. February 10, 1914, report states great improvement, gain in weight 25 pounds, pulse 82, eyes improved. She is doing her customary work.

CASE 15. G5228. J. S. H. Male, age 47. Examined August 25, 1905. *History:* Mild attack eight years prior to examination. Seven years later goiter was noted, with nervousness, exophthalmos and pulse 140. Symptoms most severe the past four months. *Examination:* Typical exophthalmic goiter. *Operation:* August 28, 1905, thyroidectomy. February 10, 1914, patient reports that he is cured. He has gained forty pounds in weight; eyes, heart, and pulse normal; no nervousness.

CASE 16. G4782½. P. H. L. Male, age 30. Examined May 15, 1905. *History:* Patient had had symptoms of tachycardia, nervousness, and tremor for a year and a half. About eight months prior to examination exophthalmos and goiter were noted. Symptoms steadily progressive. *Examination:* Definite exophthalmos, enlarged thyroid, pulse 130. *Operation:* May 16, 1905, thyroidectomy. February 10, 1914, patient reported cured. Thirty-eight pounds gain in weight, pulse and heart normal, eyes moderate.

CASE 17. P2617. G. H. Female, married, age 44. Examined May 11, 1905. *History:* One child 16 years of age; goiter of several years' duration, increased during past year with nervousness, protrusion of eyes, palpitation, and tremor. *Examination:* Firm thyroid; heart dilated; pulse 120. *Operation:* May 13, 1905, thyroidectomy. February 10, 1914, patient cured; gain of thirty-five pounds in weight; pulse and heart normal; eyes greatly improved. She is doing her usual amount of work.

CASE 18. P1657. B. L. P. Female, married, age 30. Examined June 11, 1904. *History:* One child seven years of age; goiter, exophthalmos, tachycardia, and tremor for two years. *Examination:* Moderate exophthalmos; slight tremor; pulse 100. *Operation:* June 15, 1904, thyroidectomy. February 10, 1914, patient reported cured; pulse and heart normal; eyes normal; no nervousness; gain of twenty pounds in weight.

It may be well to note here the effect of pregnancy during the progress of the disease or following the operation. A few of these patients are in much better health during pregnancy; however, in the majority the symptoms are worse. I believe that the risk to life incident to pregnancy and labor is less than from abortion, which rarely should be produced, since most of these patients improve after childbirth.

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THE ORIGIN AND NATURE OF FŒTAL MOVEMENTS[1]

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In an article published in 1912 on the "Pathogenesis of the Hæmorrhagic Diseases of the New-born,"[2] it was shown that all those diseases commonly known as Buhl's disease, Winckel's disease, melæna neonatorum, etc., are probably different expressions of an asphyxial process. This conclusion was based in part on the successful reproduction of the various anatomical changes characteristic of the diseases mentioned, by permanently diminishing the blood supply to the pregnant uterus of an animal shortly before labor. At that time it was noted that when any considerable disturbance of circulation was produced, violent movements of the fœtuses occurred. This observation suggested the query, Are all fœtal movements the expressions of an asphyxia?

In studying the literature I was impressed by the fact that very little has been done to analyze the factors concerned in the production of fœtal movements; and almost none of this has been experimental. Braxton Hicks[3] was apparently one of the first to apply experimental methods to the study of this question, and it was he who devised the means of graphically recording fœtal movements which Ahlfeld[4] later employed in a more detailed investigation. Ahlfeld in fact apparently has gone into the question of fœtal movements more extensively than any one else. He states that there are many kinds recognized through the abdominal walls; and he classifies them into extremity movements, stretching movements, physiological contractions of the diaphragm, and physiological intra-uterine respiratory movements. He states also that there are still other kinds which have not yet been recognized through the abdominal walls; namely, swallowing and sucking movements. His experimental work was confined to the making of curves, with Hicks's apparatus, of movements which he has designated as physiological intra-uterine respiratory movements. His reason for considering them as such is based chiefly on the fact that they are periodically recurring, nearly rhythmical, occurring about sixty to seventy times per minute, and that by means of his curves he claimed to have recognized a coincident rising of the thorax with a sinking of the abdominal region. He considers the extremity movements to be never shock-like but gliding in character, performed especially when the fœtus finds need to change to a more favorable position. The stretching movements are stated to be sometimes gradual and at other times jerky. Those which are designated as physiological contractions of the diaphragm give rise to shock-like sensations felt by the mother, and they are said to resemble hiccup.

Although Ahlfeld has been one of the few who have introduced experimental methods into the study of this question, yet his work apparently has been done exclusively on the human subject, and hence under conditions which he could not control so accurately as if he had used animals. He seems not even to have made direct observations on animals to determine whether in the opened uterus it is possible to observe the rhythmical respiratory movements going on in the fœtus which he claims to have found by means of his curves. He does, however, record an instance of having observed in the case of a child born within the membranes five shallow respiratory movements before opening the membranes. But these occurred with intervening pauses of from one and one-half to two seconds and were not such as his curves would indicate. His conclusions, however, have been accepted by Ferroni,[5] who obtained similar curves from pregnant women. But Ducci,[6] who also obtained similar curves from the human subject, was unable to recognize

[2] Graham: J. Exper. Med., 1912, xv, 307.

[3] Hicks. "On Recording the Fœtal Movements by Means of a Gastrograph," Tr. Lond. Obst. Soc., 1880, xxii, 134.

[4] Ahlfeld. "Lehrbuch der Geburtshilfe," p. 63. Leipzig, 1903, Grunow.

[5] "Osservazioni e richerche sui movimenti ritimici fetali intrauterini," Ann. di Ostet. e Gin., 1899, xxi, p. 897.

[6] Cit. by Ahlfeld.

[1] Received for publication, May 5, 1914.

these movements in animals. Also, serious objections to Ahlfeld's conclusions have been made by Runge [1] and Ohlshausen.[2] Runge conceded the possibility of respiratory movements *in utero;* but in two experiments with the opened uterus of pregnant sheep he failed to see rhythmical respiratory efforts. Respiratory movements occurred only after compression of the navel. Ohlshausen raised the point that the movements recorded by Ahlfeld were probably a transmission of aorta pulsations. In a later article Ahlfeld [3] replied by stating that in a former article he had shown that aorta pulsations had nothing to do with his curves. At any rate, beyond the attempt to explain this one kind of fœtal movement, the existence of which he has not proven beyond criticism, Ahlfeld's work does nothing to explain the underlying factors involved in the causation of the various kinds of fœtal movements.

The interpretation of the shocklike sensations experienced by pregnant women on the basis of fœtal hiccup, or physiological contractions of the diaphragm, seems to have originated with Mermann,[4] although he later withdrew this idea. Ahlfeld, however, and, more recently, Commandeur,[5] have concurred in this interpretation.

The present study shows that any influence which produces a more or less severe asphyxia of the fœtus induces active fœtal movements. By the methods used it has been possible to determine that these movements, while chiefly respiratory in character, also frequently consist of movements of the head and extremities of such a sort that these could easily be responsible for shocklike sensations felt by a pregnant woman. They were violent and jerky in character, produced sometimes by a forcible extension of the whole body, although more often they consisted merely of a sudden extension of the head with or without a simultaneous opening of the mouth. Often they did resemble a hiccup, although it was impossible to determine whether or not the diaphragm actually contracted. Extremity movements occurred both as a part of a sudden extension of the whole body as well as independently. They were sometimes distinctly shocklike, particularly when involving the hind extremities, and at other times gliding in character. In one experiment, under the influence of CO_2 inhalation, the movements were so violent that the fœtus nearly ruptured the membranes, and immediately after making a small slit in them it propelled itself out with a violent extension of the trunk and extremities. This occurred even before the liquor amnii had had time to escape; and, therefore, apparently the exposure of the skin to the air was not an important factor. In short, *all of the various kinds of fœtal movements described by Ahlfeld except the swallowing and sucking movements can arise out of the one underlying condition of asphyxia.* But the observed respiratory movements were neither rapidly recurring nor rhythmical. Moreover, it has been found that these movements also follow the direct inhalation of carbon dioxide by the mother. The results, therefore, may perhaps be attributed to the effects of an increased H-ion concentration in the blood of the fœtus; and probably of greatest importance usually is the H-ion which comes from carbonic acid. Fœtal movements in general, therefore, are brought into relation with the known facts of the origin of respiratory movements in the adult, the convulsive movements of CO_2 poisoning, and the hyperpnœa and other muscular reflexes following the increased concentrations of such acids as lactic acid, etc., in the blood. Roughly speaking, late in the pregnancy, the degree of asphyxia (i. e., the concentration of H-ion in the blood of the fœtus), up to the point of paralysis of the nerve centers, determines whether the fœtal movements are merely respiratory in nature or are more violent and associated with movements of the extremities as well. It was observed, however, that the movements were intensified if there was present the additional stimulus of exposure of the skin to the air. This fact has been recognized before. Runge [6]

[1] "Die Ursache der Lungenathmung des Neugeborenen," Arch. f. Gynäk., 1894, xlvi, 512.

[2] "Über den ersten Schrei," Berl. klin. Wchnschr., 1894, xxxi, 1079.

[3] "Kritische Besprechung einiger neueren Arbeiten geburtshülflicher Inhalts," Ztschr. f. Geburtsh. u. Gynäk., 1895, xxxii, 150.

[4] "Klonischer Zwerchfellskrampf im Fötalleben," Centralbl.f.Gynäk., 1880, iv, p. 377.

[5] "Note sur les Mouvements Rythmés du Fœtus," Lyon méd., 1898, lxxxviii, 429.

[6] Loc. cit.

showed experimentally that various reflexes other than respiratory movements occurred on irritation of the skin after opening the fœtal membranes. Ahlfeld also noticed that in the case, previously cited, of the infant born in the unbroken membranes, deeper respirations occurred after opening the membranes than before. Ahlfeld's contention that rhythmical respiratory movements take place in the fœtus was not confirmed in the present study. But possibly the smallness of the experimental animals used (guinea pigs) precluded the recognition of rapid superficial respiratory movements.

It is an especially interesting fact that it is possible for the young to remain alive after birth even although they may have made many respiratory movements *in utero*. This fact is shown very well in Experiment 10, and it seems to indicate that the liquor amnii does not enter the lungs. Why it does not enter is by no means clear. One would expect that if the respiratory passages were open the fluid would be forced into the lungs, even without respiratory movements, because of the tendency for the pressure to be equalized in all directions. It is possible that these passages are opened only as the result of the action of such a factor as the irritation of the skin by exposure to the air.

All the experiments have been made with guinea pigs far advanced in pregnancy. The method adopted for direct observation of the fœtal movements has been opening the uterus but leaving the membranes and placenta attachment undisturbed. The transparency of the membranes allows an excellent view of the contained fœtus. The possibility that cooling of the fœtus, even in the enclosed membranes, was a more important factor than the methods taken to produce a hypercapnia was excluded by the fact that without opening the abdominal wall violent shocklike movements could be easily induced, both by direct inhalation of CO_2 by the mother and by occlusion of the mother's trachea.

The methods used to produce an asphyxia of the fœtus have been: (1) ligation of uterine vessels, (2) occlusion of the trachea of the mother, (3) direct inhalation of CO_2 by the mother. In all the experiments which involved opening of the abdomen a light ether anæsthesia was maintained throughout; and the animals were killed with ether at the close of the experiments without being allowed to regain consciousness.

Protocols follow:

LIGATION OF UTERINE VESSELS

Experiment 1. A large pregnant guinea pig was lightly anæsthetized with ether, and a medium laparotomy incision was made. The uterus containing three fœtuses was delivered out of the abdomen and clamps were applied to four branches of the uterine vessels occluding both artery and vein in each case. Within thirty seconds distinct movements could be made out within the uterus, which increased in violence and became associated also with uterine contractions during the next few seconds. At the end of one and one-half minutes the uterus and membranes were rapidly incised and the fœtuses, which seemed to be near term, were exposed to view leaving the placental attachments intact. The movements were now seen to consist for the most part of what were apparently attempts at respiration. At irregular intervals, averaging five to ten seconds apart, the jaws were suddenly thrown open in a gasping manner, the head was sometimes violently extended on the neck, and often a sudden violent extension of one or more of the extremities occurred. After three and one-half minutes the movements had entirely ceased and the fœtuses were considered dead. The mother was then killed with ether. Some of the movements noted in this experiment resembled hiccups.

Experiment 2. Performed in practically the same manner as above. In this case the uterus contained only two fœtuses. After exposing to view as in Experiment 1, it was noted that one at irregular intervals forcibly extended the whole body. The other showed essentially the same phenomena as already described in Experiment 1.

Experiment 3. Performed in practically the same way as Experiments 1 and 2, except that after discovering that there were only two fœtuses it was decided to investigate the relative differences produced by occlusion of veins on one side and arteries on the other. The idea was that if the movements are an expression of an excessive CO_2 tension rather than a lack of oxygen, they should be more pronounced in that fœtus on the side with the occluded veins. It was found to be rather difficult to ligate separately either the arteries or veins because of their small size, but finally three veins on one side and three arteries and a vein on the other side, all of about equal size, were ligated. One vein was ligated with the arteries to prevent hæmorrhage, since it was torn during the separation and ligation of the arterial branch. The ligation of the vessels consumed about ten minutes' time; and during the necessary manipulation rather active fœtal movements were noted. The uterus was not opened

until after the ligation of the vessels. Because of the difficulty in establishing the conditions, it was impossible to compare with accuracy one fœtus with the other. Nevertheless there seemed to be no doubt that occlusion of the veins alone produced much more violent movements than did the ligation of the arteries and one vein. This would seem to favor the idea that the movements are due to an increased CO_2 tension rather than to a diminished oxygen tension.

OCCLUSION OF THE TRACHEA

Experiment 4. As before, the abdomen was opened under light anæsthesia and the uterus exposed to view. Only one fœtus was found. Pressure on the trachea of the mother was exerted until violent dyspnœa and marked cyanosis occurred. During the development of the dyspnœa and cyanosis active movements of the fœtus were seen similar to those which have already been described; and they increased in intensity with the increase in the mother's cyanosis. Also it was interesting to note that the hitherto quiet intestines of the mother showed marked peristaltic waves after the cyanosis became severe and that the most active fœtal movements occurred during the period in which the peristalsis was most violent.

Experiment 5. In this experiment the uterus was neither delivered out of the abdomen nor opened; but it was allowed to remain in place. A good view of it was obtained by wide retraction of the abdominal wound. Two fœtuses were found; and active shocklike movements of both followed the occlusion of the mother's trachea.

DIRECT INHALATION OF CO_2

Experiment 6. As before, the abdomen was opened under ether anæsthesia and a uterus containing three fœtuses, approximately at term, was disclosed. The uterus was opened, leaving the membranes intact, according to the method already described. A stream of CO_2 was then run from a tank into the ether inhaler and after twelve seconds active fœtal movements began similar in nature to those already described. All three fœtuses showed the phenomena about equally, but the movements usually were not simultaneous in all. As the cyanosis and dyspnœa of the mother increased the frequency and intensity of the fœtal movements likewise increased. In this experiment there was noted an occasional rather slow movement of the extremities which resembled the gliding movements described by Ahlfeld.

Experiment 7. Performed in a manner identical to Experiment 6, except that a stream of CO_2 was run into the inhaler both before and after opening the uterus. The results under both sets of conditions agreed so closely that it was apparent that the method involving the opening of the uterus was not in itself an important factor in the production of the fœtal movements. In this experiment, also, the uterus contained three fœtuses.

CONTROL EXPERIMENTS

In order to determine the influence of the operative manipulation, including such factors as cooling, drying, etc., three experiments were performed in which no operative manipulation was done.

Experiment 8. Under light ether anæsthesia the trachea was occluded by pressure. With the onset of cyanosis and dyspnœa active jerky movements of the fœtuses could be seen through the unopened abdominal wall. They agreed closely with those already described, although, of course, they could not be analyzed so accurately. They could be easily distinguished from peristaltic waves.

Experiment 9. A repetition of the preceding experiment. The results obtained were essentially the same as those mentioned under Experiment 8.

Experiment 10. Active violent fœtal movements were produced on four occasions during pregnancy by the direct inhalation of CO_2. The gas was administered at intervals of about four days apart. At each time it was given for a period of about ten minutes, without anæsthesia or any other manipulation than merely fastening the pig to a board. Although no laparotomy was made, it was very easy to distinguish the violent jerky movements of the fœtuses in various parts of the abdomen; so that there seemed to be no doubt that the whole litter was equally affected. Within twelve hours after the last inhalation of CO_2 a litter of four pigs was born during the night. When found in the morning one pig was dead, but the other three were active and normal in every respect. The room was very cold during the night; and it is possible that the death of one of the pigs was largely due to exposure. This experiment shows the interesting fact that it is possible for a healthy litter to be born within a few hours after inducing violent respiratory movements *in utero*. It is clear, then, that the amount of fluid aspirated into the lungs by a fœtus undergoing respiratory movements is negligible. Otherwise these pigs could not have breathed normally and lived after birth.

Experiment 11. This experiment was performed to determine whether the factor of breathing chilled air was important in the experiments in which inhalation of CO_2 was used, since it is well known that a stream of CO_2 will produce a marked lowering of temperature. Violent fœtal movements were produced by causing a pregnant guinea pig to inhale CO_2; and the temperature of the inhaler into which the gas was passing was noted at 21° C. The pig was then allowed to breathe air at a temperature of 12° C. for the same length of time, but no fœtal movements occurred.

SUMMARY

Asphyxia of the fœtus of sufficient grade will result in the production of fœtal movements, more or less severe. The movements

thus produced vary from mere attempts at respiration, sometimes resembling the fœtal hiccup of Mermann, to more general muscular contractions, simulating the general convulsions of CO_2 poisoning seen in the adult. At times these are sufficiently violent to be seen through the abdominal wall as distinct shocks. All of the generally recognized varieties of fœtal movements, except those concerned with swallowing and sucking, have been produced experimentally by methods which induced an asphyxia of the fœtus. The intra-uterine respiratory efforts are not accompanied by an aspiration of any appreciable quantity of fluid into the lungs and hence are not incompatible with life after birth. The explanation of this is not clear, but probably the contact of the skin with the air is an important factor in opening up the respiratory passages. The hypothetical intra-uterine rhythmical respiratory movements of Ahlfeld (physiologische intra-uterine Athmungsbewegungen) were not observed. The suggestion is made that the various active movements of the fœtus experienced by many pregnant women in the latter part of pregnancy are expressions of a more or less severe, but usually transient, asphyxia of the fœtus.

MASTITIS LACTANTIA

Etiology, Behavior, Treatment, and Sequelæ[1]

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IT is of the very greatest obstetric, pediatric, and surgical importance that the general practitioner, as well as the specialist, give the most careful study to the predisposition to, etiology, and behavior of the infections of the "*nursing*" breast, in order that they may the more carefully carry out both ante-partem, and post-partem prophylaxis, as well as intelligently and promptly institute the necessary radical surgical measures when unavoidable infections do occur, and thereby avoid those changes in the milk-secreting acini, ducts, and intra-acinous connective tissue and stroma, which not only may inhibit the lactations function and jeopardize the life of the present and indeed successive infants, but which also may jeopardize that of the mother, from sepsis, as well as perhaps later predispose the breast to malignant growths.

The human mammæ lie normally between the third and sixth or seventh ribs and between the parasternal and anterior axillary lines bilaterally and are very highly organized, interfascial, rete malpighian glands belonging to the sebaceous type, which have attained the dignity of milk-secreting, racemose glands composed of radiating, grape-bunch-like ducts and peripheral acini, separated from each other by a (fat-holding) interacinous connective-tissue stroma, in which lie the nutrient blood-vessels, lymphatics, and nerves of the milk acini.

Under the stimulation of pregnancy these glands gradually undergo increased stroma loosening, vascularity, lymphatic development, and hypertrophy, and hyperplasia of, and colostrum secretion by the acini-cells, in order after labor to actively secrete milk if nursed, to still sustain the child (parasitically) for a period of time, about equal to that which the child was carried *in utero*, when they again undergo involution, though never entirely to their nulliparous condition.

The terminal (peripherally situated) active acini are lined by a single layer of large, round, or cubical milk-secreting epithelial cells, while leading from these terminal acini are fine ducts lined by a cylindrical epithelium, debouching (proximally) into the fifteen or twenty main ducti galactiferi, which widen in a sinus-like manner just before opening

[1] Read before the Chicago Gynecological Society, April 17, 1914. (See discussion, p. 423.)

on the surface of the centrally situated nipple, surrounded by its pigmented areola, with its five to fifteen Montgomery's, and many ordinary sebaceous and sweat glands.

Inflammations during nursing in the mammary gland region may be primarily:

(*a*) *Supra-mammary*, by infection gaining access through some superficial skin abrasion over any part of the breast outside of the nipple region, or

(*b*) *True mammary lactations infections*, which are either *primarily endoductal and intra-acinous* from bacteria deposited on or resident in the nipple skin, without or with nipple abrasions or fissures, or, indeed, from bacteria gaining access to or already resident in the milk-ducts themselves (just as occurs so frequently in the ducts of the lower grade sebaceous glands in other regions); or *primarily extra-acinous* from the infected nipple atria via the radiating interductal and interacinous stroma lymphatics.

(*c*) *By contiguity;* e. g., from a primary infection in the axillary glands extending to the mammary gland periphery or a vertebral (contouring along the rib) or subjacent primary rib or sternum (often tubercular); osteomyelitis or empyema necessitatis also direct retro-mammary infection when giving salt solutions under the breasts.

(*d*) *Hæmatogenous;* e. g., in mumps, cryptogenetic, metastatic, or pyæmic. (Those occasional spontaneous breast disturbances in the new-born as demonstrated by Koelliker, and the cases of real mastitis neonatorum, formerly so common, due to the traumata of squeezing for witch's milk by poorly instructed nurses and midwives, which happily occur much less frequently to-day, also the cases of furunculosis and supra- and true mammary infections both during the developmental activity and irritation of puberty, or during menstruation or pregnancy, or in diabetics (Cameron), perhaps likewise often from contact infection or trauma as occasionally seen in factory workers, who lean on benches or work tools, and erysipelas do not come within the scope of this paper.)

The "*nursing*" *breast*, subjected as it is to the hyperæmia of suction and to the traumata of the child's mouth, is very liable to the possible occurrence, and contact infection of, abrasions or fissures, especially common at the apex and base of the nipple, often perceptible to the naked eye and even bleeding.

These very dangerous abrasions most commonly occur in the unprepared nipple-skin of primiparæ, and indeed occasionally if less often also in multiparæ in the first few days or weeks of nursing, possibly consequent on little subepidermal traumatic hæmorrhages being followed by excoriations, or the constant wetting and "*imperfect*" drying giving rise to a rhagadous eczema.

These nipple lesions are also, however, very frequently so minute and invisible as to cause no suspicion of their presence in the early stages, except perhaps for some slight smarting pain at the beginning of each nursing, and even this pain frequently lessens or even disappears within a few minutes after the often apparently healthy nipple becomes "warmed up," as it were—thereby giving undue popularity to the term "*simple stagnation mastitis*" as used by von Angerer and others; for stagnation of milk as the only cause is refuted by the rarity of breast abscess in non-nursing primiparæ and multiparæ. Neither does the occurrence of an abscess as reported by Williams in an unpredisposed multipara who had already nursed five children without infection, but in the eighth month of the sixth pregnancy suddenly develops a mammary abscess, prove the absolute absence of contact infection or trauma or both.

In consequence of this lessening or disappearance of pain, even the mother considers it a natural accompaniment to nursing and unless specially questioned does not complain, till the stagnant milk in the insufficiently emptied sini lactei (due to the pain and acute paraductal congestion and infiltration) invites endoductal infection, either by the bacteria in the skin or on the nipple abrasions, or indeed those gaining access to or already resident in the ducts themselves.

Staphylococci (albus) were found in 80 to 94 per cent of all breasts; they played a harmless rôle in the milk-ducts in health, but became pathogenic under the change of conditions caused by milk stagnation or

paraductal congestion (Williams, Bumm, Hoenigmann, Koestlin).

The writer would suggest the possible lack of breast-duct resistance to this (oft present) coccus in some primiparæ who apparently develop infection almost immediately the child is placed at the breast, much the same as often occurs in cases of stubborn furunculosis in other parts of the body, which occasionally have their origin in the hyperæmia caused simply by a brisk rubbing of the skin, and the protracted course of which often subsides only after the use of autovaccines.

Endoductitis, and *ductitis mammæ* probably vary widely in their behavior and sequelæ according to their extent and severity; e. g., if very mild it may probably only cause some slight (large) duct epithelial irritation. In more protracted and acute cases the infection may reach the finer ducts or even the acini and the infection and infiltration invade secondarily the intra-acinous loculi septa.

The study of microscopic sections convinces the most skeptical of the undoubted occurtence of a primary endoductal infection and primary endo-acinitis, by the marked involvement of the intra-acinous septa and the often entire non-involvement of the interacinous stroma.

On the same slide, side by side, one may find perfectly healthy acini with clear-cut cubical milk-secreting cells; and other acini with apparently an increase of cells, which stain much less sharply, while the intra-acinous septa between the infected acini-loculi are thickened and small-cell infiltrated; and again others in which the intra-acinous septa are so markedly small-cell infiltrated and thickened that the acini-loculi are difficult to discern indeed under the low power; the acini have almost the appearance of a mass of small infiltrating cells only, while the main (interacinous) gland stroma itself is often entirely uninvolved, except for some spots of periductal infiltration here and there.

If resolution of the intra-acinous infection should now occur, it is very possible that the intra-acinous connective-tissue septa induration and thickening might give rise to a circumscribed or diffuse "interstitial acinitis" as noted by Mintz, with atrophy of the milk-secreting acini and entire loss of their milk-secreting function, or if the acini epithelium be markedly multiplied to the mastitis chronica cystica (Koenig) or "maladie cystique de la mammelle of Reclus," said to be most common in the non-nursing-para, or in the advanced stages even to that varied combination of changes which result in the so-called adenofibroma, which has been paraded under such a multiplicity of names, because of the preponderance of new-growth being in one case in the ducts and another in the acini epithelium and still another in the sarcoma like multiplication of the connective tissue.

It is also very simple to understand that in other cases where the infection had only slightly, or indeed not reached the acini, that there may occur, either due to the predominating paraductal connective-tissue indurations thickening and duct distortion, or following an actual loss of duct epithelium with ulceration in the ducts, a duct stricture or even atresia with the formation of the rare retention cysts or galactocele with their oily or butter-like contents.

In contra-distinction to the foregoing, an infection of the (open) nipple abrasions and fissures may be followed by a primary radiating lymphangitis and primary small-celled infiltration of the interacinous connective-tissue or main gland stroma and only, if severe or long continued, some secondary effect on the acini and duct epithelium, indeed von Angerer believes lymphangitis the most frequent.

The *end-result* in severe breast infection, whether beginning as a ductitis, probably most often staphylococcic, or whether beginning as a lymphangitis, probably most often streptococcic, is often abscess.

Williams, quoting Rubeska, mentions the staphylococcus, either aureus or albus or both, as present in fifteen (93¾ per cent), and streptococcus once (6¼ per cent), in sixteen cases of breast abscess, and also says that Sarfert demonstrated the gonococcus in one case.

If there be a parental or nurse gonorrhœa present, even though there be no gonorrhœal ophthalmia or stomatitis neonatorum, the contamination of the nipple with gonorrhœal

infection, with its predilection to affect cylindrical epithelium-lined ducts, might easily occur in the breast and indeed also prepare the soil for mixed infections.

The writer has also repeatedly noted the concomitance of abscess in the mother's breast and thrush stomatitis of the nursing infant.

From clinical observation there are also cases of apparently synchronous ductitis and lymphangitis.

Of the mammary abscesses, 15 per cent are in the non-pregnant, 5 per cent in pregnancy, and 79 per cent in the nursing woman (Billroth), and of these latter, 67 per cent are nursing primiparæ. They vary so extremely in site and behavior that they demand a special description.

(*a*) The supramammary abscess is really an intersuperficial fascial abscess; i. e., it is situated in the connective tissue and fat between the superficial-superficial and the reflected deep-superficial fasciæ. These superficial abscesses do not involve the gland substance unless neglected, when they may rupture deeply through the deep layer of superficial fascia into the para-acinous connective tissue or infection of this latter occur via the paravenous lymphatics or septa and give rise secondarily to a true mammary abscess; usually, however, the supramammary abscess allows of easy and early recognition, and also, due to its early tendency "to point" and fluctuate, is incised promptly.

(*b*) The true mammary abscess, whether primarily from duct or primarily from lymphatic infection or both, should include the nipple, paraductal (areola), and para-acinous abscesses. The foci of suppuration are often multiple, later becoming confluent, forming one large abscess. It usually involves one section of the breast, most often in the external aspect.

In one multipara (seven months after labor) with large bilateral abscesses operated by the writer at the Presbyterian Hospital, the abscess of the right breast was on the axillary aspect, and that of the left breast on the sternal aspect; possibly due to the irregularity of the eruption of the child's teeth causing the abrasions.

The increased looseness of the stroma in the nursing breast makes small-celled infiltration less capable of walling in and limiting the abscess area, consequently these lactations abscesses dissect with increased ease both peripherally and proximally, and superficially, and deeply in the para-acinous connective tissue, and easily become confluent, and often of large size.

The adjacent milk-secreting acini over a more or less wide area may undergo necrosis, or with the ducts be laid bare, and pus rupture into them and be in part discharged on the nipple; though it should be always borne in mind that this pus is not always from an abscess, but may have its origin in the ducts themselves, probably leading to the erroneous impression of Kaarsberg that he cured mammary abscesses by milking the infected breast.

The axillary sub- and supraclavicular glands are usually also metastatically enlarged and tender, and in neglected cases may suppurate and rupture with multiple axillary fistulæ. Also that gland suppuration can follow nipple infection, even though no mammary abscess occur, should always be thought of as a possibility.

The depth of the true mammary abscess focus in the interacinous tissue also varies. In one case it is comparatively superficial, giving rise to an early superficial tumefaction, redness, and fluctuation, by the infection passing upwards via the paravenous lymphatics or septa or rupture through the reflected superficial fascia to the skin with pointing, and if neglected perhaps rupture externally.

In other cases the original pus focus is so deeply situated in the para-acinous connective tissue that, while there may be some slight increased local temperature and pain and even some appreciable hardness in a part of the breast, there is, at least at first, no apparent tumefaction, or even redness, and palpation elicits no fluctuation.

In these cases a chill followed by a temperature of 103° or 104° F. and very frequent pulse, with high leucocytosis, early in the puerperium may so uncomfortably simulate puerperal sepsis, especially if there be some tenderness to pressure over the hypogastrium,

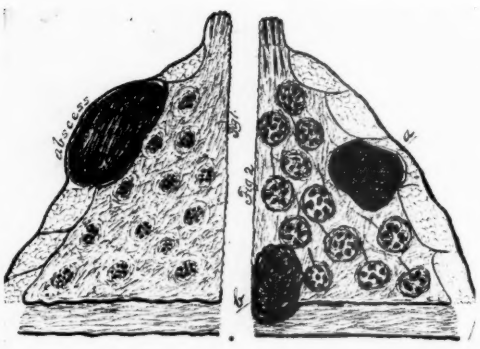


Fig. 1. Fig. 2.

Fig. 1. Schema of supramammary abscess, showing anatomic site above the deep layer of reflected superficial fascia. The mammary gland is not involved.

Fig. 2. Schema to demonstrate endoductitis, ductitis, and primary acinitis mammæ; with abscess foci (a) breaking superficially and (b) breaking retromammary.

as to cause neglect to examine the breast carefully.

This unfortunate neglect to diagnose and early incise radially the deep mammary abscess may result in deep paravenous metastasis or deep rupture through into the loose retromammary para-connective tissue, when the mammary gland as a whole usually becomes more prominent on the thorax, being raised by the retromammary pus, which may become very large in amount, especially when containing (as the writer not infrequently experienced in cases entering Cook County Hospital) gas-containing pus, probably due to colon bacilli.

The pointing of these retromammary abscesses often occurs late and usually at some dependent part, frequently the lower aspect of the breast periphery, but naturally should under no circumstances be waited for.

The *treatment*, especially of primiparæ prophylactically during pregnancy, includes very thorough daily soaping of the nipple and breast with green soap to soften the often extremely thick, dirty, bacteria-holding, duct meatus obstructing, horny layer of nipple epithelium, the very thickness alone of which hinders the free flow of milk and will later cause cracks—if they occur—to gape, and so interfere with the healing process.

A wet boro-salicylic dressing occasionally at night, in which the impervious covering extends at least one and one-half inches beyond the wet dressing all around, aids materially in the softening and cleansing process.

(Alcohol to harden the nipple should be used sparingly, if at all: it dries and hardens the horny layer too much.)

The nipple should also be well pulled out nightly by the patient herself after the fifth month of pregnancy, using gradually more and more force in the pinching and pulling, and so prepare it, the ducts, and the breast for the traumata of nursing, as well as thereby improve their strength and circulation.

The post-partem prophylaxis is regular interval nursing for a consistent length of time only, followed by "immediate" washing off with watery boric solution or other antiseptic, and thorough drying and covering with an aseptic pad and keeping warm.

The routine antiseptic care of the child's mouth is also very essential.

The beginning of pain or smarting immediately when placing the baby to the breast, or the application of the alcohol test, should be followed at once by the application of wet antiseptic dressings, to be rewet every two hours, and the nursing be conducted through an aseptic shield.

The removal of the child entirely is necessary if the condition does not respond to treatment or if there be other signs of abscess formation, and one or more early long radial incisions according to the number of foci in the affected breast with the evacuation of the pus, curetting and iodization, and iodoform gauze packing or "pinned" drainage tube inserted. In one recurrent case Dr. N. Sproat Heaney actually discovered a healed-in drainage tube.

If the finger (inserted in the wound) passes into the retromammary space, a pair of forceps should at once be inserted behind the breast and a dependent transverse incision and drainage made at the lower periphery.

The absence of this latter (often extremely necessary) precaution accounts for many of the very protracted cases with the formation of multiple pus and often also milk-discharg-

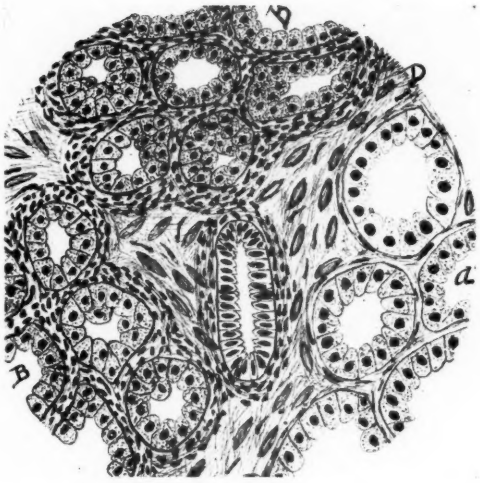


Fig. 2a. Drawing from microscopic section of ductitis and acinous mastitis: (a) Healthy acinus. (b) (b) Acini with small cell infiltration of the acini-lobuli septa and immediate para-acinous tissue. (c) Cylindric cell-lined duct surrounded by small cells. (d) The main stroma is uninvolved and healthy everywhere even between the affected acini (b) (b).

ing fistulæ, and often almost total breast destruction, with burrowing under the pectorals, perhaps involving the ribs, and into the axilla or even under the latissimus dorsi, demanding dependent drainage in the posterior axillary line with or without removal of the axillary glands.

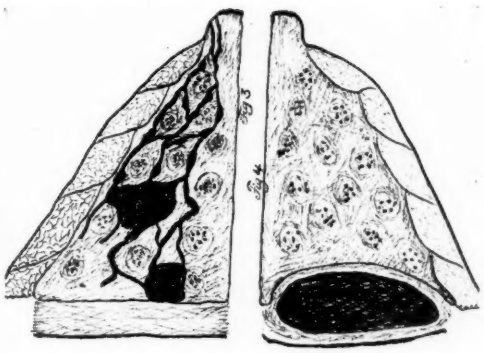


Fig. 3. Fig. 4.

Fig. 3. Schema of radiating lymphangitis mammæ in which the acini are uninvolved except at the two abscess sites; viz., (a) superficial mammary abscess breaking superficially; (b) deep abscess breaking retromammary only.

Fig. 4. Schema of primary retromammary abscess with crowding up of the as yet unaffected breast acini.

Besides the local infection, indeed, septicæmia or pyæmia may result with lethal issue in neglected cases.

Recovery of extensive loss of breast tissue is by granulation tissue, the resultant scar often together with the surrounding induration and indeed possibly deposit of lime salts may simulate or later be the site of origin of mammary carcinoma, thereby justifying the proposal to amputate the breast after the healing has occurred in cases of panmastitis.

CHRONIC PERFORATION OF PEPTIC ULCER

Report of Four Cases[1]

By J. RUSSELL VERBRYCKE, Jr., M. D., Washington, D. C.
Instructor in Gastro-Enterology in Medical Department of Georgetown University

An ulcer of the stomach or duodenum may perforate in several ways. There may be typical acute perforation, with characteristic symptoms of sudden agonizing pain followed by boardlike rigidity, peritonitis, and death if operation is not performed within a few hours. This condition is most apt to occur with ulcer of the anterior surface of the stomach.

There may be also subacute perforation with formation of an abscess cavity surrounded by adhesions. This occurs most frequently with ulcer of the posterior surface of the stomach or of the duodenum.

There may also occur what has been variously termed pinhole perforation, occult perforation, or penetrating ulcer, in which the ulcerative process has extended through all of the coats of the stomach but in which perigastric adhesions have occurred so quickly and firmly as to at once plug up the opening which is usually small.

This includes the main classes of perforated ulcer, though there are various other results which may ensue from these conditions after a variable length of time, as burrowing of an abscess, subphrenic abscess, perforation into another organ, subcutaneous emphysema, etc.

I report four cases of non-acute perforation which are of interest for several reasons. Three of these patients were seen within a period of three weeks. Two were of the occult perforation type and two were typical chronic perforations. By the term chronic perforation we mean the condition which obtains when an ulcer perforates acutely but in which death does not occur, though operation is not performed at once, and in which the perforation still exists unhealed.

Diagnosis was correctly made in three patients before operation and in two before the radiographic examination. The radiograph showed bismuth in a cavity outside of the stomach in but one of the three cases submitted to X-ray examination.

All four patients recovered. It is most unusual for any four consecutive cases of perforation to recover without immediate operative intervention. Riegel[2] says: "As a rule, perforation, with the passage of gas and stomach contents into the peritoneal cavity, leads to death in a short time. Occasionally, however, perforation seems to heal even though symptoms are exceedingly violent in the beginning. Such a cure, however, is rare and is seen only if perforation occurs when the stomach is empty. I saw a case of this kind some time ago. The patient developed all symptoms of perforation into the free abdominal cavity. Hepatic and splenic dullness disappeared and there were severe meteorism, collapse, and other symptoms. The patient recovered completely.

"Hall has gathered six other cases of a similar character from the literature and had one case."

The histories of my patients will be presented in their chronological order.

Case 1. Mr. W. T. G. was seen July 11, 1912, at 10 A. M. He had a history of digestive disturbance extending over a considerable number of years, consisting of pain coming on four hours after meals and relieved by eating. He had been seized on rising in the morning with severe abdominal cramps, starting in the epigastrium and spreading over the whole abdomen, followed by vomiting. His temperature was normal and the pulse was 80 and of good quality. There was moderate rigidity and general tenderness not localized to any one point.

A perforated ulcer was at once thought of, but because of his good general condition and absence of much shock, the possibility of simple enterospasm was considered and he was given morphine, one-fourth grain, repeated in twenty-five minutes, partly to relieve the intense pain and partly as a diagnostic measure, since it can be said that any abdominal cramps which are not relieved by one-half grain of morphine have an organic cause, usually surgical, and are not due to simple enterospasm.

[2] Nothnagel, p. 594.

[1] Read before the Medical Society of the District of Columbia, March 25, 1914.

Fig. 1. Case 2. Perforation of gastric ulcer. Note A, Spot of bismuth above lesser curvature cavity of the perforation in gastrohepatic omentum. B, Partial hour-glass contraction. Note complete left-sided position of stomach and pylorus.

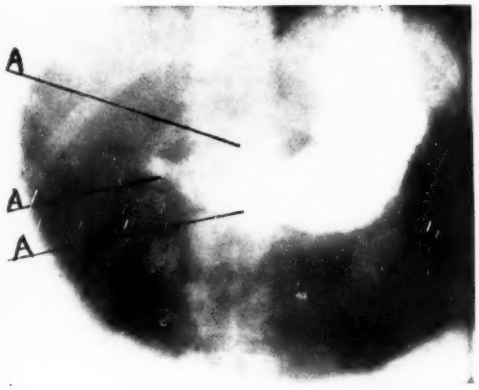


Fig. 2. Case 3. Chronic perforation of duodenal ulcer with abscess formation. A, A, A, area of non-filling and irregular filling due to distortion by dense adhesions. The perforation does not show, but under fluoroscopic examination all this part was immovable and there was enlargement of liver from congestion. Diagnosis made before operation.

Two hours later the patient was again seen and was no better. The cramps and vomiting continued, the abdomen was quite rigid, pulse was 90—though the temperature was normal, and the face was pale and covered with profuse perspiration. His leucocyte count was 21,000 with about 90 per cent polymorphonuclears.

A positive diagnosis of perforated duodenal ulcer was made and concurred in by Dr. C. S. White. He was at once moved to the hospital for operation but another leucocyte count, immediately after admission, showed no increase and, as his symptoms appeared slightly less marked, it was thought to be a pin hole perforation which was becoming automatically sealed up by adhesions. It was therefore decided to postpone operation and have blood-counts made every hour.

The patient improved and was put upon medical treatment for ulcer which was shown by occult blood and other tests to be present. After a month's treatment he was apparently well and has had no recurrence.

This is the only patient in the series in whom diagnosis was not proven by radiograph or operation, but there can be little doubt as to the correctness of the diagnosis.

Case 2. Mr. G. E. W., age 55, was referred to me by Dr. Robert Trimble, December 26, 1913, complaining of pain on the left side of the epigastrium running downward, a pain as if the intestine were being pulled on. In addition to this pain under the costal border, he had a hunger pain in the mid-epigastrium, before meals and often at night, and this pain was always relieved by vomiting. There were, in addition, acid waterbrash, bloating, etc. These symptoms were of four years' duration and during that time he had lost seventy pounds. The patient was a very ill-looking man with almost a cachectic appearance. He had a marked myocarditis, the apex beat being in the eighth interspace, nipple line, of wavelike character and intermitting badly.

The abdomen was scaphoid with irritable recti. The splashing sound was confined to the left side of the abdomen, not even extending to the midline. There was a point of tenderness in the mid-epigastrium and another very markedly tender spot in the left hypochondrium just below the border of the ribs. There was a feeling of an indefinite mass in the upper epigastrium.

The test breakfast was not given, but examination of the vomitus showed free HCl 36 and total acidity 46 and there was one particle of food taken twelve hours before. Occult blood was faint in both stomach contents and the stool.

A diagnosis was made of ulcer of the stomach and he was put to bed, but pain and vomiting persisted so that it was necessary to radiograph him several days later. Radiographic examination by Dr. A. C. Christie showed that the stomach was fixed in position and entirely on the left side of the abdomen. There was a partial hour-glass contraction with a spot of bismuth above the stomach, separated from it, fixed in position, and constant in all pictures and under the fluoroscope, which showed that this point exactly corresponded to the tender point (Fig. 1). Diagnosis was made of ulcer of the

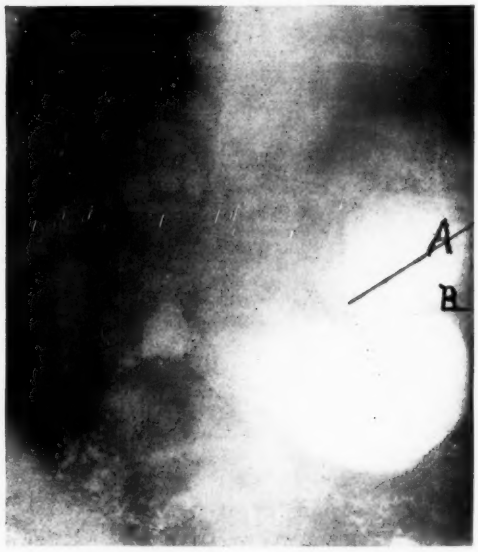


Fig. 3. Case 4. Hour-glass stomach with occult perforation of gastric ulcer. A, position of ulcer and perforation which does not show. B, complete hour-glass contraction.

lesser curvature with hour-glass contraction and chronic perforation.

Close questioning brought out the fact that two months previously while at his office he was suddenly thrown to the floor with violent abdominal pain and became hysterical. Six men held him down and chloroform was administered to quiet him. He was thought to have pure hysteria and the next day was able to return to his office but this was undoubtedly the time of the perforation.

Operation by Dr. C. S. White disclosed indurated ulcer on the lesser curvature, the size of an egg with an hour-glass contraction and perforation into the gastrohepatic omentum. Adhesions were so dense that they were not disturbed and it was impossible to do anything other than a gastro-enterostomy, high up above the contraction. The patient made an uneventful recovery and has gained wonderfully since the operation.

Case 3. Mr. A. F., a clerk, age 21, consulted me December 26, 1913. His health had been good all his life until two months before, when he began to have pain, starting two hours after meals. He had often wakened at night with it.

On December 17th, while at work, he was suddenly seized with vomiting and abdominal cramps, so severe that he could not move. He was taken to the Emergency Hospital and after two days moved to his home. He had improved somewhat from that time but had constant soreness in the right hypochondrium and tenderness over the liver. He had lost weight rapidly.

At the time that I saw him he appeared ill. The abdomen was scaphoid with recti tense and irritable. There was a point of decided tenderness under the border of the ribs on the right side, in the region of the gall-bladder. There also seemed to be some tenderness all over the region of the liver. There was no occult blood in the fæces or stomach contents which showed free acid 74 and total acidity 88. Leucocyte count was 13,300.

A perforated duodenal ulcer was the first diagnosis, but it was then thought that he had cholecystitis because of the location of the tenderness, the leucocytosis, and the absence of occult blood.

He improved to a certain point and even returned to work one day, but then lost ground and on January 5, 1914, three weeks after the acute onset, I returned to my first diagnosis of chronic perforation and submitted him to Dr. Christie for radiographic examination.

The stomach in this case, also, was found to occupy a decided left-sided position and was fixed. The liver was seen to be considerably enlarged and congested. While the perforation did not show, there was noted a marked defect and irregular filling of the whole pyloric antrum and first part of the duodenum (Fig. 2).

Operation, the next morning, by Dr. White, revealed a mass of dense adhesions between the gall-bladder, pylorus, duodenum, and lower border of the liver enclosing a large abscess due to perforation of a duodenal ulcer. A gastro-enterostomy was performed and the abcsess cavity drained. For a time he was very septic from the large amount of pus which formed, but he quickly and apparently perfectly recovered.

Case 4. Mrs. A. O., age 36, was referred to me December 11, 1913, by Dr. Leon Martel. She had been troubled with her stomach for twelve years, her chief symptoms being gas in the stomach and bowels with attacks of headache and vomiting. She had attacks of vomiting lasting several days but usually the attack seemed migrainous in character, the vomiting relieving the headache. She had occasional pain but with no regularity and not colicky or cramplike in character.

On examination she was found to be fairly well built and healthy looking. Examination was negative except for the following points: The right kidney was palpable about two inches below the costal border and slightly tender. The abdomen was well formed with normal recti. Splashing sound was obtained over the upper half of the epigastrium only. There was slight tenderness over the whole epigastrium and down the right side to the cæcum which appeared thickened and was plainly palpable. A well localized and very tender spot was found on the left side in the nipple line two inches above the level of the navel.

The urine contained a very faint trace of albumin, hyaline casts, and a faint excess of indican. There was no occult blood in the stool. One hour after a test breakfast only five ccm. of thick contents were

obtained with a considerable excess of mucus and free HCl 40 and total acidity 50.

Ulcer was considered but ruled out because of the absence of occult blood, the character of the stomach contents, and the absence of any very positive symptoms or signs. Diagnosis was made of chronic constipation with acid gastric catarrh, migraine, and nephroptosis.

She was put on treatment and daily lavage instituted. There was a quantity of mucus and considerable food retention found at each washing. She improved subjectively at once and had no more headache or vomiting, but at each lavage there was just as much retention as at first so that it was evident that she had some obstruction, though the rice and raisin test was negative, so radiographic examination was made January 2, 1914 (Fig. 3). There was revealed an almost complete hour-glass stomach with an ulcer on the lesser curvature which was so indurated that its outlines could be seen in some of the plates.

Operation was advised and in view of the location of the ulcer, high on the lesser curvature, it was determined if possible to excise the ulcer. The operation was performed January 19, 1914, by Dr. Martel, and revealed findings exactly as indicated by the radiograph. There were dense adhesions about the site of the ulcer and as these were separated, a perforation was disclosed, nearly large enough to admit the tip of the little finger, but which had been firmly sealed up. A considerable part of the ulcer was posterior to this opening, a saddle ulcer. An incision about two inches long was made along the lesser curvature, then extended backward and the ulcer excised and stomach closed. A gastro-gastrostomy was then done, but it was feared that this might not give enough of an opening, so nearly the whole of the anterior surface of the stomach was divided and reunited so as to give a clearance of a couple of inches.

The patient made a beautiful and uneventful recovery, without any evidence of shock, in spite of the magnitude of the work done on her stomach. She has not been completely relieved of her symptoms yet, and a radiograph made March 9, 1914, showed there was a spastic contraction at the site of the old constriction. Under the fluoroscope this spasm was seen to relax at times. It has not been decided as yet whether the spasm is due to a recurrence of the ulcer or not but there is no occult blood to indicate such a condition. She has been put on a cream diet with atropine, and if this is not productive of good results it may be necessary at some future time to do a gastro-enterostomy high up above the constriction.

Chronic perforation, the type of termination of ulcer represented by these four patients, is so very rare that it has been thought advisable to place their histories on record[1].

[1] Since writing this report I have had a fifth case of chronic perforation. It would seem that the condition is more common than has been supposed or that I have had a most unusual experience.

OBSERVATIONS OF INGUINAL LIPOMATA BASED ON 154 HERNIOTOMIES

By KELLOGG SPEED, M. D., Chicago

SOME time ago E. W. Andrews in demonstrating his imbrication operation for hernia suggested that the inguinal lipomata found so often in connection with hernial sacs, or as the lone cause of inguinal bulgings, were of importance as a causative factor of hernia primarily and if not removed were a factor in recurrence. This fact he had noted before in his article on hernia in the American Textbook of Surgery, but not emphatically, and the literature has scant reference to the rôle of lipomata in hernia. It was considered of enough importance to warrant the collection of statistical observations looking toward determination of the frequency of these fatty masses, their relative size and position, and this article desires to call attention to their presence and advise their removal in all inguinal herniæ by ligation as high up as the sac is cut off.

If left behind, even in transplantation of the cord, regardless of the type of operation used to cure the hernia, they tend to cause a bulging of the inguinal canal; and as a part of the properitoneal fat, being attached to it, they are subject to some downward strain in increased abdominal tension from any cause and exert traction on the peritoneal surface at or about the internal ring. This traction may cause the formation of a true hernia and give a recurrence following operation for radical cure. Personal observation has been

made on 154 operations for hernia and notes were made while the pathology of each operation was fresh in mind.

These cases cover patients of all ages from six months to 83 years and all lengths of duration of the hernia as well as all patients regardless of their weight. Some cases were taken from Dr. Andrews' clinic at Mercy Hospital, the others from my personal cases at Mercy Hospital and Cook County Hospital.

The lipomata of the inguinal region divide themselves into two natural classes: those found in the direct type and those found in the indirect type of hernia. Those connected with the direct type are usually of broad base; they bulge up from the weakened area in the abdominal wall where the conjoint tendon is deficient and may be closely adherent to or cover a large part of the circumference of the sac. When the sac of direct hernia is merely a bulging of the peritoneal wall on account of its lack of support by the muscles which should act as a retaining surface, the fatty mass may cover this in a uniform manner and depth or come out laterally in a separate mass. When separate, this fat adjunct of the protrusion in most cases takes its origin above the peritoneal bulging and may pass down over it and extend on down into the inguinal canal out of the external ring. Should this fat mass be dissected apart, a smaller and more distinct sac can be found and the removal of the lipomatous material favors a non-recurrence of the hernia. When direct sacs are small we are not in the habit of opening them at all nor attempting to ligate them off, but, by bringing down over them the curtain of the conjoint tendon and external oblique and attaching it to Poupart's ligament, we feel that sufficient repair has been done to cure the hernia. Removal of the excess fat with careful ligation of its blood supply lessens the amount of tissue that tends to bulge, and favors the cure. Ligation lessens the chance of hæmatoma formation which might cause a pulling out of the deep stitches by pressure, or if unfortunately infected might cause abscess formation.

In indirect hernia the lipomata assume different shapes dividing into:

1. Long pedunculated masses slightly lobulated and covered with a more or less true peritoneal-like covering which looks like a very thin sac, taking their blood supply from above.

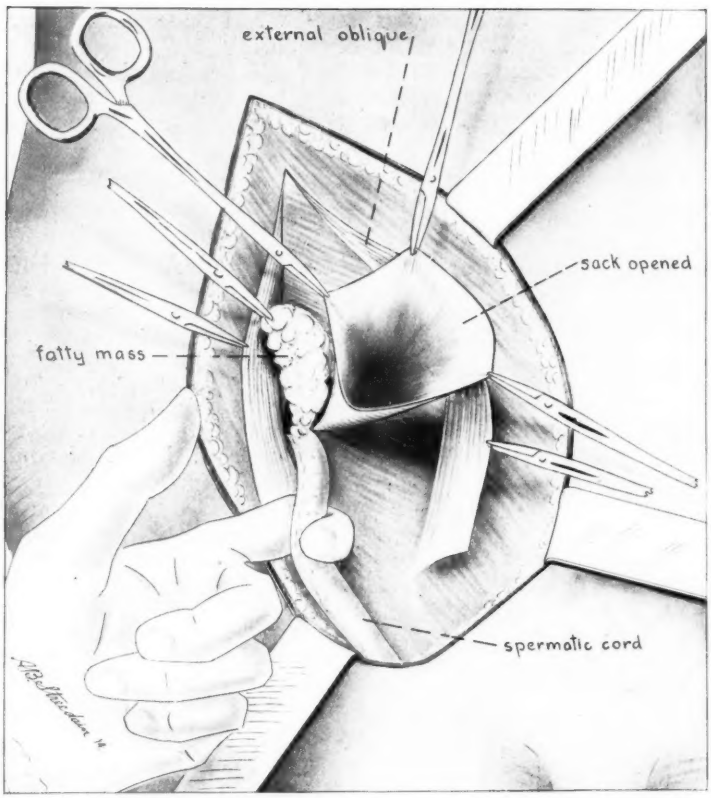
2. Broad, bulging masses originating behind the cord at the internal ring and bulging out in the general direction of the cord, lying posterior to it; or,

3. Distinct fatty masses incorporated in the tissues of the cord with an attenuated neck at the internal ring.

These appear to take origin from the properitoneal fat, as their blood supply and continuity extend from this tissue and in some cases seem to have followed down in the wake of the sac, or in others seem to have preceded the true hernial sac and to have broken a way for it. In most cases they are found to originate from the lower aspect of the internal ring, are much longer than the sac, and seek a pathway downward in direction of the cord or round ligament, forming more or less of a distinct pedunculated mass along the cord adherent to or separated from it, bulging out the inguinal canal and seeming to act as a space-forming wedge behind which the true hernial protrusion may follow. These may pass down to and out of the external ring.

Hernial protrusions are found clinically which on examination give the distinct bulging and coughing impulse, and one feels sure that there is a distinct sac to be found; yet on opening the canal nothing more than a bulging mass of fat can be found occupying the external ring. These masses may conceal behind them a small sac and hence should be carefully pulled apart or followed up inside the internal ring and the presence or absence of sac determined before they are ligated and cut off.

Observation develops that most of these lipomata originate at the inner and posterior margin of the internal ring; they may, however, be found springing from the anterior surface and lying in front of the cord, and in some instances have been found in double and triple form, each lipoma taking a separate point of origin. Each mass can be separately stripped out and ligated. Naturally, fat individuals are more apt to have these lipomata



Semidiagrammatic drawing from actual operation illustrating inguinal canal opened, sac dissected from cord and opened, and separate fatty mass extending down into internal ring.

than thin individuals, as they have a greater amount of properitoneal fat, but the lipomata are also found with great frequency in those of normal or even a subnormal amount of adipose tissue.

In herniotomy perhaps too little attention is paid to freeing the sac neck around the internal ring for a distance of one to two cm. after it has been freed from the cord tissues. The sac should be held up taut and the index finger, gauze-covered, should sweep well around the internal ring, freeing the sac neck which the constant pull stretches further out into the wound. If ligated as in the ordinary run of cases, the ligature should always be deeper down—i. e., nearer the abdomen—than the white line of the old thickened constriction ring which is present in practically every sac. In making this freeing dissection around the sac neck and pulling it down, one often brings into view hidden lipomatous masses, possibly of very broad base, lobulated, and as a rule pointed out from the internal ring and the general direction of the cord. These can be included in the ligature and removed even if the sac neck has to be further dissected up to get to their base. The amount of time involved is small and the peritoneal surface is sufficiently elastic to allow much stretching. If they remain, or if the sac has been tied off too long with a tendency for the peritoneal surface to bulge out from the internal ring

instead of being well retracted back and offering no depression into which omentum or other abdominal content may tend to wedge, these masses of fat become larger, are inclined to slip or wedge into this small extrusion and cause gradual recurrence of the cured hernia.

Of 154 herniotomies performed, lipomata were found present in the opened canal 73 times, giving a percentage of 47.4.

CONCERNING THE FORMATION OF A NEW VAGINA IN THE CASE OF CONGENITAL VAGINAL MALFORMATION

By Dr. GOTTHARD SCHUBERT, Gynecologist, Beuthen, Upper Silesia

ALTHOUGH only a few years have elapsed since the first experiments were made in trying to form an artificial vagina for those individuals that are affected with congenital vaginal malformation, the literature concerning this subject has recently increased considerably. It was Krömer (1), who critically examined the literature existing up to this time, and wrote his essay: "Die plastische Neubildung der Scheide bei partiellem oder totalem Defect." I may be permitted, therefore, to pass over methods which up to this date were used to correct this deformity. I shall confine myself to a description of the development of this young branch of surgical gynecology.

Originally there were employed pedunculated cutaneous flaps cut out of the upper thigh or the small labia (of the vulva), for the purpose of lining a canal which was formed (without cutting) between the rectum and the bladder, and which represented the new vagina. Some surgeons used peritoneum, others employed pieces of the skin (which were transplanted from any convenient place), for the purpose of lining the cul-de-sac. Even the intestinal mucous membrane of rabbits was employed for the same purpose. But all these methods failed to obtain any practical result, inasmuch as the transplanted pieces of skin soon shrank and the artificial canal was gradually occluded.

Matters began to go the right way from the very moment when mucous membrane was employed for the purpose of lining the artificial canal. Gersuny (2) was the first to try an experiment of this kind. The canal which was to represent the artificial vagina was lined with a piece of mucous membrane which had been cut out from the rectum. He proceeded in the following manner: After having divided the perineum and the sphincter ani, he cut a strip of mucous membrane from the anterior wall of the ampulla without interrupting its connection with the rectum near the plica vesico-rectalis; this piece was then laid on the back wall of the bladder as far as the orifice of the urethra and here fixed by suture. The wound which was thus caused in the ampulla was closed by three rows of sutures, the margins of the wound having been loosened. The anterior wall of the artificial vagina was thus formed by a piece of mucous membrane from the rectum, while the surface of a wound; i. e., the anterior wall of the rectum which had been united by suture, formed the back wall. The sphincter ani was not united lest the strain due to evacuations should interfere with the course of healing of the sutures. A tampon covered with gutta percha paper was introduced into this artificial vagina in order to prevent the tract of wound from cohering. This method was employed in four cases, three times by Gersuny himself and once by Puppel (3). Excepting that his patients had to wear a dilator (a conical vulcanite plug) in order to prevent the vagina from narrowing, Gersuny obtained tolerably satisfactory results. Puppel was not so successful — a rectal fistula and a contraction of the vagina in consequence of tension of the tissue produced a total failure.

There is no denying the fact that Gersuny's

method shows a considerable progress in the formation of an artificial vagina in the case of absolute malformation; nevertheless, it proved insufficient. The fact that the piece of mucous membrane, which is covered with bacteria, is, during the whole length of the operation, in continual contact with the surrounding surface of the wound, renders a "prima intentio" of the suture in the rectum a doubtful thing. It is not to be wondered at that fistulæ appeared in the cases of Gersuny and Puppel. The permanent wearing of a dilator in the artificial vagina is another detriment which ought not to be connected with an ideal operation. The dividing of the sphincter without its being united by suture is, in most cases, connected with a partial incontinence; i. e., patients will be able to retain evacuations of an ordinary consistency, but neither diarrhœa nor flatus. Last, but not least, I do not think a vagina of the above description permanently suitable for coition.

The first operator who employed a piece cut from the rectum for the purpose of forming an artificial vagina was Sueguireff (4). He proceeded in a manner which appears monstrous to us. He divided the rectum in the region of the os sacrum; the lower end was formed into a cul-de-sac; the upper end was attached by suture to the skin, thus representing the excretory duct of an artificial anus. According to Krömer's report (loc. cit.), Sueguireff divided the bridge between anus and vulva and closed the wound by pulling into the lateral margins (the question is, which?); thus was formed a kind of channel leading to the piece of rectum which was destined for coition. The leading idea was to profit from the contact of the external sexual organs for the purpose of coition and to place the entrance to posterior cul-de-sac as far forward as possible. According to this method Sueguireff has operated on three patients.

I do not hesitate to criticise Sueguireff's procedure in the sharpest manner, as it brought about a more serious disease than the want of a vagina means. What a mischief is a preternatural anus for him who is possessed with it! Aside from this, there is no denying the fact that the patients, during the whole length of life, must expect serious injury to their health, as every anus preternaturalis, however deep it may be placed, causes serious disorders of the digestive tract. In my opinion, there is not a single extenuating fact in Sueguireff's procedure that should influence other surgeons to follow his example; for, concerning the methods of correcting the malformation of a vagina, we should, without Sueguireff, have arrived at the same stage of progress today, as those methods, which, properly speaking, are the only available ones, were invented by men who I do not suppose had any knowledge of Sueguireff's procedure.

Fig. 1. First stage of the operation. Circumcision of the hymen and preparation of the rectum out of the sphincter ani (3 cm. long).

We have seen that all the methods mentioned above proved absolute failures or brought about only slightly satisfactory results. Baldwin's method was the first to obtain really useful results (5). Basing his theory upon experiments on dead bodies, he proposed using a loop cut from the small intestine for the purpose of forming an artificial vagina.

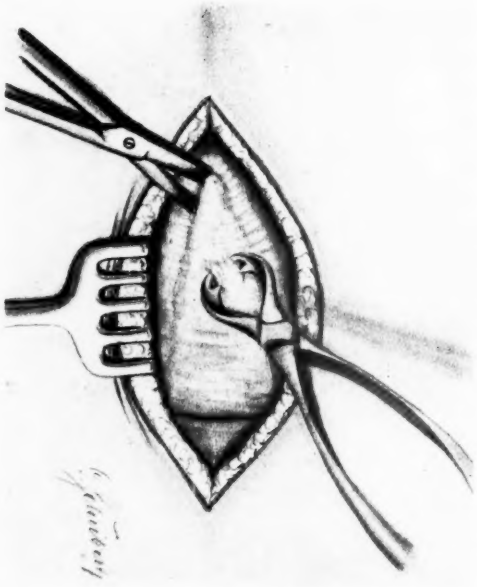


Fig. 2. Enucleation and extirpation of the coccyx.

In 1907 Baldwin tried this method. In one case the vagina of a patient had been contracted by scars in consequence of repeated dystocia, and had thus become unfit for coition. Baldwin cut out the undermost part of the ileum. A Murphy button combined the two ends of the divided intestinal tube, while the dissected piece was formed into a cul-de-sac. By means of a silk thread which was put around the middle of the loop, this piece of ileum was drawn into a tube which was formed into a cul-de-sac between the rectum and the bladder; then it was united by suture with the orifice of the vulva and at last opened there. Thus was formed a double vagina, the wall of which was later gradually divided. This operation was crowned by a lasting and satisfactory result.

In four other cases Baldwin proceeded in the same way and was successful in each case.

Without having any knowledge of Baldwin's method, Mori at Ira, in Japan, in the same year formed a vagina by cutting a sling out of the small intestine, but without doubling it. Even two years after the operation the result remained satisfactory (6). In the same year, Haeberlin (7) proposed remedying congenital vaginal malformation by implanting a loop cut out of the small intestine.

This method was employed by the following surgeons: Abadie (8), Prince Louis Ferdinand (Müller [9]), Stöckel (10), Papanicol (11), Hulbau (12), and Bumm (13).

Before critically examining the methods referred to I shall speak of other operations in which also were employed pieces cut from the intestine for the above-mentioned purpose.

Amann (14) used in his case the anterior wall of the rectum. His patient had a recto-vulvar fistula, in consequence of stuprum. The ampulla recti of his patient being unusually wide, Amann, by means of intestinal clamps, pulled down an upper fold of the anterior wall after having thoroughly divided the bridge between the fistula, the anus, and the sphincter. Then the fold was transversely split and entirely isolated. The upper margin of the wound being attached by suture to the orifice of the vulva, the place of the former fistula now formed the orifice of the vagina, while the lower margin of the wound was united with the sphincter, and closed, in this way, the divided rectum. By uniting the levatores ani, Amann formed a septum vaginale. Then he united the sphincter by suture and finished the operation by skin-suture of the perineum. The result was highly satisfactory. Amann himself declares that his method is suitable only in the case of a wide ampulla recti. He proposes, therefore, to employ the rectum to form a new vagina in every other case.

A rather complicated way of forming an artificial vagina was chosen by Albrecht (15). He opened the peritoneum in the sacral way, pulled down the flexura romana, closed the peritoneum, divided the flexura at its transition to the rectum, and, pulling out the upper end through the vulva, attached it here by suture, finally implanting the upper part of the rectum laterally in the flexura. At first the evacuation made its way *per vaginam*. After a few days, he divided the implanted flexura (which represented the vagina) about 12 cm. above the vulva and united the surfaces of the two wounds by suture.

Albrecht employed this very radical and complicated method in three cases, obtaining a satisfactory result in two. In a third case the vagina became entirely necrotic. This was a fatal failure. Fæcal fistulæ appeared in each of these three cases and had to be closed by a later operation.

Finally, one word more about Popoff's (16) method. He employed the rectum for the purpose of forming a vagina by cutting out the ampulla recti and placing it in the region of the vagina, while the upper end of the rectum was pulled through the anal wound and united by suture with the sphincter, which had remained entire.

Without having had any knowledge of Amann's proposal, which had not yet been published, nor of Popoff's procedure, which, even up to this day, I know only from short reports (I know only the former methods in which pedunculated patches of the skin or pieces cut from the small intestine were employed) — I say, without having had any knowledge of these above-mentioned methods, I followed absolutely a course of my own in a case which I shall describe (17). I formed an artificial vagina by means of a piece of the rectum, which absolutely answered the purpose. Three other cases offered much opportunity of technically improving my method, so that at this moment, if I may say so, matters have reached the highest attainable degree of perfection.

I proceed in the following manner: The patient is lying on the right side. I extirpate the hymen completely without penetrating deep into the body, then follows circumcision of the anus, the dissecting of the rectum from the sphincter (Fig. 1) (about 3 cm. long) after a moderate dilatation of the sphincter, and, at last, a dressing forceps covered with a thick tampon is introduced into the rectum.

I make a cut to the bone (10 cm. long) above the coccyx, beginning 5 cm. above the anus; the fascia is pushed aside and the coccyx is laid bare and seized with the bone forceps. On gently raising the latter, the sacroccygeal synchondrosis becomes visible. While the joint of the coccyx is pressed toward the rectum, the synchondrosis is divided with a bone-knife. The coccyx is (by means of a pair of

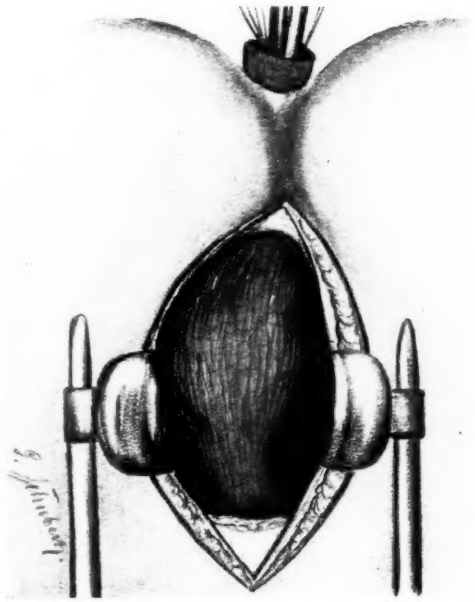


Fig. 3. Showing the rectum pulled through the sacral wound by means of an introduced forceps.

scissors) enucleated; I advance from its point by means of planing the bone. The two terminal branches of the arteria sacralis are held by two forceps. The fascia pelvis is divided by a longitudinal incision. The rectum is pulled forth by means of a dressing forceps and isolated about 12 cm. above the anus by means of bilateral ligatures above and below the place which is to be divided. The rectum having been so far isolated that a bridle bandage can be put round it, the rectum pelvicum is pulled down. The stretching connecting bundles are doubly tied and divided, until the part which is to be cut through may easily be pulled down toward the anal region. The peritoneum is not opened and remains invisible. Now the rectum is pinched by means of two intestinal clamps, and the intestinal tube is divided between the clamps. The surface of the upper incision is covered with a tampon saturated with lysol, while the lower wound is immediately closed by way of a continuous suture which, after the removal of the lower clamp, is secured by a double row of button-sutures. The cul-de-sac

Fig. 4. Showing the general situation respecting the wound and the displacement at the end of the operation.

which has thus been formed is, by means of two sutures, fixed as high as possible to the ligamentum sacro-spinosum. Now I penetrate with my finger through the perforated hymen toward the coccygeal wound, and widen this canal so that two fingers can easily pass through it. The anal piece of the rectum which was cut out from the sphincter is drawn through this canal toward the newly formed orifice of the vulva, by means of some interrupted sutures fixed to the margin of the skin. The upper end of the divided rectum, which was closed with a clamp, is in a similar way put through the sphincter ani, at first by means of some hidden sutures fixed to the sphincter itself, and afterward to the external anal skin by means of some interrupted sutures. A thin sterile strip of gauze is put in the coccygeal wound and pulled through the lower corner of the wound. The rest of the wound is closed. The newly formed vagina is laid bare by means of a speculum, cleansed from phlegm, and plugged with a sterile gauze swab. At last, at the end of the operation, a drain of India rubber covered with gauze is introduced into the rectum.

Following this method I have operated on four patients. The healing took a regular course without any trouble. The primary and secondary results were excellent. I never heard of any complaint, either at the end of the convalescence or after many years of observation. This method was employed by Flöel (18), by Franqué (19), by Krömer (20), by Strassmann of Berlin, and by Engelmann of Dortmund. Nine cases in which this method was employed have been observed up to this time. All these surgeons approve of the simple manner of the execution and report extremely satisfactory results.

If we now compare the different methods which I have described above, with my procedure, it seems to me evident that my method possesses such important advantages that it deserves to be called the most simple and the best of all. In my opinion, there is hardly a possibility of Albrecht's procedure competing with the rectum method. Up to this time there is none who has employed Albrecht's method, and I think there will be none, his method being too complicated and its results too problematic. (Remember the cases mentioned above: in one case, gangrene of the new-formed vagina; in all three cases, fæcal fistulæ.) Thus I think there will hardly be a surgeon found who will follow his example. Concerning the main effect,— a vagina fit for coition,— there is only one method which can compete with my procedure; that is the small intestine method according to Baldwin, Mori, and Haeberlin. Respecting simplicity and security of life, there is no rivaling my method. Baldwin's method seems to me too dangerous, and I agree with Albrecht, who thinks that Baldwin's method offers too little security of life and that the loosening of an intestinal suture may cause the death of the patient. It happened in the case of Abadie (21), who operated by Baldwin's method, that a patient, in consequence of an intestinal suture not being tight enough and causing a fæcal fistula, had only a narrow escape of the most serious complications.

In spite of all our modern procedures, in spite of the most brilliant skill in execution, the small intestine method for the purpose of forming a new vagina represents a hazardous enterprise on which I should not like to venture. But setting aside the loosening of an intestinal suture, the laparotomy in itself, or

only one mistake in the aseptic apparatus, under certain circumstances is sufficient to destroy the life which has been entrusted to us. Therefore, Stöckel (22) is quite right in saying: "Who would venture to assert that the discipline of the operation theater is able to render impossible such mistakes in the procedure that may easily become fatal? There is no denying the fact that mortality reaches a higher percentage with laparotomy than with other operations." This incontestable truth cannot be gainsaid, however excellent the perfection of surgery may be.

Medicinal literature shows a great many operations executed according to Baldwin's method, but these cases do not at all prove that all these operations had satisfactory results. It is nothing but human not to publish those cases which turned out badly. I do not hesitate to confess that even my method cannot afford any proof of its bringing about only successful results in every future case. But, nevertheless, I am convinced that, concerning my method, nothing but an unforeseen accident is able to cause an unfortunate result. In my opinion, there is not the slightest doubt that the small intestine method is connected with serious dangers to life and health which hardly come into question in connection with my method.

I pass over all the casualties and dangers connected with the small intestine method which, besides peritonitis, appear during convalescence, such as thrombosis of the mesenteric vessels, or ileus after the operation, and, supposing that the operation is always crowned with a satisfactory result, there are nevertheless in this method so many deficiencies that they are sufficient in themselves to cause us to reject the method of forming a vagina by means of a small intestine sling.

The fact that my operation can be executed from its beginning to the end with the patient in a lateral position, while Baldwin takes his course at first per vaginam, afterwards per laparotomiam, and finally per vaginam again, — I say, this fact shows that Baldwin's method requires much time and endangers the asepsis, which circumstances do not prove Baldwin's method to be an acceptable one.

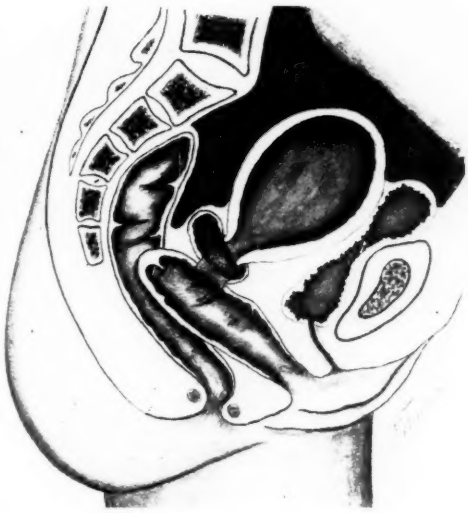


Fig. 5. Displacement at the end of a vaginal operation in the case of hæmatometra.

It may happen that after the opening of the abdomen an extremely short mensenterium is found. In this case, there is nothing else to be done but to stop the operation and to close the abdomen, and all labor is lost. The scar on the abdomen, even if no hernia follows, is an everlasting memorial of this operation, not only for the patient, but also for her husband. There is no denying the fact that the mesenteric section of which the implanted sling is formed, being very much stretched in itself, will cause much pain whenever a stretching of the vertebral column is required by any function. The cord which goes through the small pelvis seems to me a sufficient reason for permanent fear of an ileus. A stricture appearing at the anastomosa of the intestinal loop, and which we cannot entirely avoid even by forming a wide lumen, may require a new operation or cause lasting troubles. Besides this, the adhesions, which in consequence of the operation appear on the mesenterium and the intestinal loop, very often cause the most disagreeable conditions.

It is known that Stöckel, at the end of his operation (Baldwin's method), has succeeded in proving the existence of coli bacteria in the peritoneum. Through experiments it

has been satisfactorily proved that, in case the surgeon is not free from germs, adhesions will appear in the peritoneum. I am of the opinion that there is no possibility of applying Baldwin's method in the case of high-lying hæmatocolpos, in which case the forming of a new vagina for the purpose of restoring the possibility of conception must be for a surgeon a highly ideal aim.

It is undeniable that the thin intestinal wall, which during a coition separates the penis from the abdominal cavity, means a permanent and great danger for the possessor. Bumm of Berlin (23) covered the intestinal tube with the existing rudimentary annexions, thinking to have found a way of diminishing the danger. On the basis of the same apprehensions, Ruge, of Frankfurt, has per laparotomiam removed a piece of flexura sigmoidea which on account of its thick coat seemed to him most fit for the formation of a new vagina. Under these circumstances, the canal being lined with mucous membrane, the appearance of hernia lies within the bounds of possibility, which, so far as I know, none of Baldwin's adherents has taken into consideration.

Injuries to the bladder and rectum are very possible, as the canal which has to receive the intestinal tube is formed into a cul-de-sac. What effect the secretion of the implanted piece of ileum will have on the exterior genitals and the surrounding parts remains to be seen. In order to prevent the intestinal loop from secreting too much, Stöckel has prescribed a special diet to a patient who had been operated on according to Baldwin's method.

Without further circumlocution I come to the question, Facing all these important difficulties, how does my method stand? Concerning the scar, it is not to be seen, and thus it comes that in two cases the husband has not the slightest intelligence of the correction in the body of his wife. Two months after the operation, Krömer (loc. cit.) exhibited to his students a patient who had been operated on according to my method. Krömer's assistant, who had been studying for several years, failed to discover the suture at the vaginal orifice, and not knowing that an artificial vagina had been found, he was of the opinion that he had seen the diagnostic signs of a catarrh of the cervix uteri. The scar in the rima ani is only to be found by one who knows the whole previous history of the scar. Hernia of the scar, with all its inconvenient effects, is absolutely out of question, so far as my method is concerned. Likewise we avoid all the damages and dangers brought on by laparotomy because the peritoneum does not come into sight at all. There is no reason why the secretion of the rectum should have a detrimental influence upon the exterior skin, as nature itself has destined this piece of intestine to act as an excretory duct. During a two years' period of observation, none of my patients whom I have operated on had any cause of complaint in this respect. There is no possibility of injuring the bladder, as it is not necessary to form a tract of wound in the region of the bladder for the purpose of implanting the piece of intestine. But now it does not admit of any doubt that in the case of high-lying hæmatocolpos or not complicated hæmatometra, my method offers an excellent way for a lasting discharge of menstrual blood, it soon promises a fair prospect of restoring procreative power, which purpose can hardly be attained by the small-intestine method, mainly because it would be necessary to open hæmatocolpos before the implanting of the intestinal loop. In this case the peritoneum is greatly exposed to the danger of becoming infected, which would very much increase the insecurity of the dangerous action. Also in the case of hæmatometra it would be necessary to make an opening for want of room.

I am sorry to say that I never had occasion to form a new vagina in the case of the above-mentioned malformation. In my opinion, the process of operation would be as follows: At first the new vagina is formed out of a piece of the rectum regardless of the existing hæmatocolpos or hæmatometra. After the convalescence, the hæmatocolpos is opened, and, by plugging, the edges of the wound are prevented from uniting. In the case of hæmatometra connected with hæmatosalpinx, it is necessary at first to remove hæmatosalpinx by laparotomy, in order to undertake, later on, the formation of a new vag-

ina. On the basis of theoretical considerations, some surgeons have found in my method deficiencies, which, however, in practice have not come into existence. For instance, some adherents of other methods have given expression to the apprehension that the implanted piece of rectum might become gangrenous, that the sphincter might be exposed to a disturbance of function, and that the operation itself might be too difficult. But these deficiencies exist only in theory. My method is often compared to the operations of carcinoma recti and to the difficulties connected with it, but one forgets that these are things not to be confounded. There is a great difference between my method and the others. Whereas in the one case the carcinoma together with the surrounding tissue is extirpated as completely as possible, I try to retain everything. The colon pelvicum, which had been pulled down, is always surrounded by connective tissue; it is not pulled, as often occurs with operations of carcinoma, through a wound canal that is deprived of the connective tissue. Therefore the colon is not exposed to any disturbance in the matter of nutrition, nor the sphincter to any disturbance of function. Therefore, I repeat, those imperfections which by way of theoretical considerations have been imputed to my method do not exist practically, especially according to the present experiences. There is no reason whatever to fear gangrene of the rectum; no less groundless is the fear of greater technical difficulties, which, I suppose, has caused the majority of the surgeons to prefer the small intestine method in spite of the existing apprehensions.

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SOME OF THE RESULTS OF NEGLECTED CHRONIC INTESTINAL STASIS [1]

By ALFRED C. JORDAN, M. D., CAMB.; M. R. C. P., London

THE subject of chronic intestinal stasis has grown enormously in magnitude and importance since its first enunciation by Sir Arbuthnot Lane. Consequently it is impossible to cover the entire field to-night, even in the briefest manner. I propose to give an outline of some of the end-results in neglected cases, indicating the manner in which the stasis has caused these results.

Chronic intestinal stasis means the habitual undue retention of the contents of the bowel in some or all parts of its length, and the consequences — local and general — arising from the retention.

The large intestine is a very usual site of stagnation of fæces, and Metchnikoff, in his splendid writings, attributes all the consequences of alimentary toxæmia to this cause. His view received wide acceptance, and undoubtedly there are many cases in which much toxic absorption goes on from the stagnant large intestine. We must remember, however, that the large intestine is accustomed to deal with microbes, and that it has a considerable power of rendering them innocuous. The retention of hard, stagnant fæces in the large intestine also produces local evils, due to the chronic irritation set up by their presence. Colitis is one of them; there are frequent small evacuations containing mucus, and the large bowel (or the latter part of it) gets into a state of tonic constriction, so that its lumen, as shown by a bismuth meal, is always narrow, containing only a fine streak of bismuth, while the first portions of the big bowel are constantly filled with stagnant fæces. The long-continued irritation is apt to set up a disease still more disastrous; namely, cancer. Several parts of the large intestine are specially prone to be affected in this way: the cæcum and rectum, where large quantities of hard fæces often accumulate, and at points where bands form, and obstruct the lumen of the bowel, viz., the iliac colon and the transverse colon just beyond the hepatic flexure. This is only one of the ways in which chronic intestinal stasis leads to the appearance of cancer — by direct irritation.

As already explained the large intestine has considerable power of dealing with microbic infection; the small intestine, however, is sterile in health, and has not this power. When the contents of the lower ileum are dammed back at the ileocæcal entrance by the full cæcum, stagnation occurs in the last coils of the ileum; these coils are then infected by microbes which find their way from the cæcum, and the toxins absorbed from them poison the system and give rise to the constitutional changes found in the subjects of chronic intestinal stasis. Dr. J. T. Case has proved the existence of incompetence of the ileocæcal valve in the subjects of stasis; undoubtedly this facilitates the entry of microbes to the small intestine from the cæcum. The first effect of the overloading of the lower ileal coils is to make them drop from their normal position above the pelvic brim into the pelvis. In dropping they pull upon the mesentery. In feeble subjects (especially women) the attachments of the mesentery drop, allowing the bowel to fall without effort to prevent it; in more robust persons, however, the drag upon the mesentery of the lower ileum, exerted whenever the patient is upright, results in the formation of a thickening of the mesentery at the point (or points) where the pull is greatest. This thickening is the beginning of an ileal kink (Lane's kink). It represents the attempt of nature to prevent the fall of the viscera. Unfortunately the bowel is held up at one point only, and in the erect posture the cæcum and ileum fall on either side of this fixed point, so that an actual obstruction is created, aggravating the ileal stasis it was meant, by nature, to relieve. Here we have an instance of a "vicious circle"; there are many in the history of intestinal stasis. It is clear, then, that the ileal kink is not the

[1] Abstract of an address delivered before the Chicago Medical Society on April 22, 1914.

original cause of the stasis; it is an effect of the stasis, though when it occurs it aggravates the stasis. Some of the very worst cases of stasis are those in which no ileal kink occurs, the bowel dropping in these feeble subjects without any attempt at resistance by the organism. The terminal coil of the ileum hypertrophies in these cases, as in all cases of stasis, but if the cæcum occupies the pelvis (which is usually the case), the terminal ileum is out of reach; the only positive evidence of stasis in the ileum is, then, that afforded by the X-ray investigation, which proves the prolonged retention of the bismuth in this region.

The effect of the overloading of the lower ileal coils is not confined to these coils; the downward pull affects the whole mesentery of the small intestine, and the jejunum is pulled down at its upper end, and is thus kinked upon the duodenum, which is (normally) fixed at its termination. Behind this duodenojejunal kink the duodenum becomes distended: its width is often double the normal, and the length of its vertical portion five or even six inches instead of three, the normal length. The appearance of the "static" duodenum on X-ray examination is most striking. Its powerful peristaltic contractions are seen to be ineffectual against the kink, in marked contrast to the normal duodenum, which expels its contents without difficulty and without delay into the jejunum. The X-rays furnish perfect proof of the dependence of duodenal distention upon ileal stasis. We never find one without the other, and we never find a normal duodenum associated with an appreciable amount of ileal stasis.

The distended duodenum is infected with microbes which have ascended from the stagnant lower ileum; thus it is apt to become ulcerated, and chronic duodenal ulcers can always be shown, by X-ray investigation, to occur in the distended duodenums of stasis. The first part of the duodenum is usually more dilated than any other, and it is here that the ulcer is found. The biliary and pancreatic ducts become infected from the duodenum, and we get cholecystitis and gallstones in the subjects of intestinal stasis. The pancreas is always hard and nodular in these subjects; this is found at operations; eventually carcinoma of the head of the pancreas is apt to appear — another untoward result of neglected stasis.

The duodenal distention has its inevitable effect upon the stomach: pyloric spasm is present to prevent regurgitation from the duodenum; the spasm is apt to become persistent, and this leads to overfilling of the stomach, which cannot get rid of its contents in time to make room for the next meal. The greater curvature drops, and this is usually aided by the weight of the overloaded transverse colon. A great strain is thus put upon the pylorus, and results in the appearance of a chronic ulcer in some cases. Thus pyloric ulcers, stenosis, and cancers are other results of neglected stasis.

In some cases the liver drops, carrying the pylorus down with it; the strain is then shifted from the pylorus to a point along the lesser curvature of the stomach, and a secondary ulcer may then appear at this point. X-ray investigations furnish the most conclusive proof of the relation of these ulcers to pyloric spasm, and to chronic intestinal stasis. Ulcers of the lesser curvature lead to hour-glass constrictions, spasmodic in the first place, becoming stenotic if the ulcer heals. In a certain proportion of cases cancer supervenes upon a chronic ulcer, and I have a number of instances showing the transition from a chronic ulcer of the lesser curvature to a cancer.

The constitutional changes produced by stasis spare no tissue; the nodular breasts of stasis subjects are well known, and furnish a ready means of estimating the effect of treatment, the nodules disappearing with the relief of the stasis, but persisting in patients who are not improving, and going on, in neglected cases, to chronic cystic disease, ending in cancer.

The aortic arch becomes atheromatous at an early age in stasis subjects,— an important fact to surgeons, since patients do not stand severe operations after the arch has begun to dilate.

Chronic rheumatism of an obstinate kind is apt to occur; it clears up permanently on the successful treatment of the stasis. The thyroid gland shows characteristic changes; in

most cases it atrophies, so that the rings of the trachea are readily felt through it. Sometimes the thyroid enlarges, and the symptoms and signs of exophthalmic goiter show themselves. In other cases, again, adenomata of the thyroid are found. All these abnormalities clear up permanently on the successful treatment of the stasis.

Glycosuria occurs in some severe cases of stasis, and may end in diabetic coma—as in a recent case in which the X-ray investigation revealed evidence of extreme stasis, the duodenum being six inches in the length of its vertical part, and showing powerful "writhing" peristalsis in its attempts to overcome the duodenojejunal kink. There was great ileal stasis, and extreme stasis in the large intestine, no bismuth having passed the middle of the transverse colon after 48 hours; i. e., at a time when the whole of the bismuth would have been evacuated in a nornal subject. The transverse colon was abnormal in position, descending vertically from the hepatic flexure to the deepest part of the pelvis, making a complete loop in the pelvis, and emerging on its way to the splenic flexure.

This glycosuria is due, no doubt, to the pancreatic change already described. It is certain that the suprarenals do not escape from participation in the chronic changes of the glands, and the pigmentation of the skin seen in most stasis cases may be due to this cause.

This brief account will serve to indicate the great diversity and severity of the changes brought about by chronic intestinal stasis if neglected, and the need for a widespread understanding of the disease which has only come to be appreciated since the genius of Sir Arbuthnot Lane disclosed its nature to us.

RECENT EXPERIMENTS DEFINING THE DANGERS OF ANÆSTHESIA[1]

By YANDELL HENDERSON, Ph. D., New Haven, Connecticut
Professor of Physiology in the Yale Medical School

THE past five years have probably contributed more to precise knowledge of anæsthetics, their practical use and the real nature of their dangers than the preceding thirty. For many years there had been almost a condition of stagnation in this field. There were indeed investigations, for example those of the Hyderabad Commission on the dangers of chloroform,— a commission which, by the way, overlooked the essential point and reached a wrong conclusion. But such investigations were to a great extent merely a rattling of dry bones. There was little that was new in the technique of administration, and less that was suggestive for the opening of new fields of observation and experiment.

The conceptions of the dangers of anæsthesia were simple and unquestioned. The expressions "failure of respiration" and "failure of the heart" summed up everything. Each was a single definite process, although a few particularly broad-minded persons recognized also a "vasomotor failure." In both, or in all three, of these supposed modes of death the cause of trouble was assumed to be nothing else than an excess of anæsthetic or some vaguely guessed at weakness in the patient.

I cannot better express the renewed vitality of investigation in the field of anæsthetics than by illustrating it with some of the recent important contributions. I shall take first the work of A. Goodman Levy[2] done in Professor Cushny's laboratory at University College, London. As you are aware, the Hyderabad Commission reached the conclusion that if the administration of chloroform be pushed it will happen "999,999 times out of a million that respiration will fail before the heart." This amounted to saying that the fatalities under chloroform were mere carelessness on the part of the anæsthetists. Naturally the practical anæsthetists who had seen patients not only breathing at the

[2] Levy, Heart, 1913, iv, p. 319.

[1] Read before the American Gynecological Society, Boston, May, 1914.

moment the pulse disappeared, but even breathing vigorously for a minute or more thereafter, refused to accept such a statement.

The mistake lay in the assumption that fatalities under anæsthesia must be due to excess of the anæsthetic. This is an error which it seems extremely difficult to overcome in the minds of surgeons. They are prone to insist that "if that fool anæsthetist had not poured on too much ether (or chloroform, as the case may be) we should not have had all that trouble." Anæsthetists on the contrary are usually quite ready to recognize the fallacy, for they know as well as anyone can who has only a very inexact method of measuring dosage that trouble often comes when less rather than more has been given.

Levy's work has shown that primary heart failure under chloroform is a perfectly definite and easily induced result of very definite conditions. He quotes cases from the literature showing that one of the essential conditions of such fatalities is *light* chloroform anæsthesia. Such mischances do not occur under deep chloroform anæsthesia, for the heart is then merely depressed, and as respiration always fails first it is usually easy to effect resuscitation. It is not depression, but an abnormally intense irritability of the heart which is the condition underlying this class of fatalities.

Most of the fatalities quoted by Levy occurred either during the initiation or termination of anæsthesia. They involved beside the light anæsthesia another factor, namely, excitement, strong sensory stimulation, or an injection of adrenalin. A man was having the septum of his nose straightened. He was in excellent condition under very light anæsthesia. Some adrenalin was injected, and he promptly died. A girl had passed through an operation in excellent condition and the administration of chloroform had been discontinued. As she had a stiff knee, the surgeon forcibly flexed it. She gave a little cry and died. A man was given an insufficient amount of chloroform, so that the stage of excitement was prolonged; finally enough was given to induce a moderate depth of anæsthesia; he suddenly became pale and pulseless. In nearly all of these and similar cases respiration continued and was even abnormally vigorous after the pulse disappeared.

These are types of cases which Levy has shown are easily reproducible on animals, particularly cats. I have myself seen many such fatalities unintentionally produced in animals by timid anæsthetists. I have also repeated with entire success Levy's primary experiment in which adrenalin is administered to a cat lightly chloroformed, and have obtained exactly the same sudden heart failure and complete and irrecoverable fall of arterial pressure which Levy's experiments show.

What is it that occurs in these cases? Levy has shown by an almost excessive thoroughness of experimental demonstration that it is a condition of fibrillation of the ventricles,— delirium cordis,— a condition which, unlike mere cardiac inhibition or vagus or asphyxial standstill, is in as large an animal as man in the majority of cases practically irrecoverable.

I have tried experiments to see whether similar deaths could be produced in cats by means of adrenalin or sensory stimulation or prolonged excitement under light ether anæsthesia. A certain degree of the cardiac irregularity which is a condition precedent to delirium cordis is thus producible, but I have never obtained a complete and fatal fibrillation of the heart by this means.

Another of the modes of fatality which is now under analysis is one occurring under ether. Cathcart and Clark [1] find that under light etherization the heart in rabbits is markedly depressed by a degree of asphyxiation which is quite harmless under full anæsthesia. Exactly what this effect consists in, and how far it applies to human cases, we must await further investigations to learn. I have mentioned the observation here because, like the work of Levy, it bears out a point which was particularly emphasized in the report of the committee on anæsthesia [2] of the American Medical Association a couple of years ago,— a committee of which I was chairman,— in which the point was especially emphasized that few anæsthetic fatalities are due merely or mainly to excess of anæsthetic.

[1] Cathcart and Clark, J. of Physiol., 1913, xlvii, p. 393.

[2] J. Am. M. Ass., 1912, 1908.

As a rule they result more or less directly from incomplete anæsthesia and the stage of excitement. I may here repeat also another point made in that report, namely, that in view of what we now know of the dangers of post-operative chloroform poisoning, and of the not infrequent toxic effect on mother and child when chloroform is used in labor, it is about time that the use of chloroform should be given up altogether.

I wish to return now to the subject of partial asphyxia under light ether anæsthesia. Not very long ago I had occasion to observe a difficult subject under ether. For the most part it was administered by what is called an "open" method,— although why the term "open" should be applied to the type of mask employed I am unable to see, for the patient became at times markedly cyanosed. Part of the time a frankly rebreathing method of mask and Rovsing bag was used and when too closely applied some degree of cyanosis was observed. From the Rovsing bag I obtained samples of air which were afterwards analyzed for ether, CO_2, and oxygen. The figures obtained are shortly to be published by Dr. John Bryant, for whom I made the analyses. I may mention here, however, that throughout the series of analyses the oxygen content of the air in the bag and the patient's color showed the closest correspondence. Low oxygen in the inspired air occurred with cyanosis and a fair amount of oxygen with a good pink color. It seems to me altogether probable that if analyses had been made of air from the open mask the same correspondence would have been proved. If so, this mask was really far from open, for when the patient became rigid, not only was ether poured on in a steady stream, but the mask was also pressed down on the face until marked cyanosis occurred. The Rovsing mask and bag seemed to keep the patient a better color, in spite of the difficulties of the case, as well as to afford a better control of conditions, than did the open, drop method with which it was alternated.

From such observations I have become very skeptical regarding the distinction between open and closed methods. The so-called open method is often far from open. There is in the cone a very considerable dead space from which the patient rebreathes, and at times there appears to be (and this is much worse) a considerable mechanical obstruction to the movements of air. The "open" method as applied to ether is a very crude and unscientific procedure. In the first place more than half of the ether is volatilized during expiration and blown off into the room. That is one of the reasons why, when a refractory patient develops stormy breathing, the anæsthetist is compelled to pour on such a volume. Boothby [1] has recently demonstrated that the amount of ether in the inspired air necessary to produce and maintain anæsthesia is exactly the same in all subjects no matter whether refractory or otherwise. It is time that we recognized that although ether is for the anæsthetist a liquid it is for the patient just as distinctly a gas as is nitrous oxide. The time is close at hand, in my opinion, when in every well ordered and scientific operating room where ether is used at all, instead of its being poured as a liquid over the patient's face and into his mouth, there will be a device, — and it can be a very simple device,— on a stand at the anæsthetist's elbow, or over in the corner, or possibly even down in the basement, in which the ether will be volatilized and from which it will be conducted to the patient's nose and mouth, as if it were merely an unusually strong variety of nitrous oxide. That this idea is rapidly gaining recognition and acceptance is evidenced by the insufflation method of Meltzer, the simple and accurate device of my colleague, Dr. J. M. Flint, and most recently by the anæsthetometer of Connell.

It is at once a simpler, safer, and more scientific procedure to administer the gas which we call ether vapor than it is to handle liquid ether. In some observations on myself and others in my laboratory we merely put 5 ccm. of ether into a bottle and blew air through the bottle by means of a bellows or rotary air blower into a large bag of a capacity of 20 liters. This gives an air ether mixture of about 5.7 per cent by volume, a little less than the amount needed according to Boothby to maintain surgical anæsthesia. In our experiments after obtaining preliminary rec-

[1] Boothby. J. Pharm. & Exper. Therap., 1914, v. 379.

ords we administered this air ether mixture to each other by means of a mask and pipe precisely as if it were nitrous oxide. We continued the administration several times to the point of unconsciousness. To all of the subjects of these experiments it was a surprise to find that ether taken in this way, provided it is the best quality of ether, is not appreciably more unpleasant than nitrous oxide, which is for me rather enjoyable.

The particular object of these experiments was to determine whether there is in reality such a difference in different samples of ether as some practical anæsthetists believe. It has long seemed to me that if there is such a difference it must consist very largely in different degrees of intensity in exciting respiration. Some years ago I showed that in dogs one can administer ether so badly as to maintain for twenty or thirty minutes at a time a very excessive respiration, and that thereafter they were prone to a failure of the breathing, which without measures of resuscitation frequently proves fatal. Recently Meyer [1] working with Dr. J. S. Haldane, has confirmed on man my claims regarding the effects of pain and of ether in exciting hyperpnœa. I may perhaps remind you that one of the great advances in physiology during the past few years, especially as the result of the experiments of Haldane and of those who have worked under his inspiration, has been the proof that ordinarily the breathing is controlled not by oxygen needs but by the CO_2 output, that there is a large reserve of CO_2 stored in the body, and that if the breathing is abnormally excited and this store considerably reduced, there is certain to follow a compensatory period of reaccumulation, during which respiration is subnormal to the point of cyanosis and partial asphyxia, or in which the breathing even fails altogether. Thus, in my experiments comparing different samples of ether, the points noted were both the degree of hyperpnœa during a brief period of administration, and also the intensity and duration of the period of subnormal breathing which followed.

Briefly stated, it was found that with a grade of ether such as we buy for ordinary laboratory use in tanks of several gallons there was a marked augmentation of breathing in one subject and a fairly active hyperpnœa in another. With the best grade of ether, such as comes in small sealed cans, the excitant effects were comparatively slight, while the same ether after being kept for two months, with the addition of a few cubic centimeters of water, a ready access of air through a loose cork, and standing in a place exposed to the sunlight, gave very marked hyperpnœa in a sensitive subject and a considerable augmentation of breathing in insensitive subjects. Particular attention should be called to the fact that whenever hyperpnœa was induced it was followed by exactly such a period of subnormal breathing, Cheyne-Stokes respiration, and apnœa interrupted by deep gasps as is the well recognized result of acapnia, i. e. diminished CO_2, consequent on excessive respiration.

Such a condition of insufficient breathing is an extremely common consequence of etherization. It adds the evil influences of a more or less prolonged period of insufficient oxygen supply to the other conditions lowering the patient's vitality. It is clear that the logical procedure to prevent this is some such method of administering ether vapor as Dr. Gatch showed to be so advantageous with nitrous oxide, and also some method of administering a sufficient amount of CO_2 in the air breathed after the anæsthesia is ended to stimulate respiration to a more rapid elimination of the ether with which the body is saturated and to prevent apnœa or subnormal breathing, anoxæmia, and cyanosis.

[1] Meyer, J. Physiol., 1914, xlviii, p. 47.

OBSERVATIONS ON THE GONOCOCCUS COMPLEMENT-FIXATION TEST EMPLOYING SPECIFIC AND NON-SPECIFIC ANTIGENS [1]

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SUPPLEMENTARY to work undertaken about a year since and announced for subsequent publication in an article[2] read before the Philadelphia County Medical Society, May 28, 1913, we desire at present to summarize briefly the results obtained in an analysis of several hundred sera subjected to the complement-fixation test employing specific gonococcal and non-specific antigens.

In the performance of the complement-fixation reactions for suspected gonococcic and syphilitic infection there is little or no fundamental variance in the technique other than in the employment of different antigens. Whether it be the Wassermann or the gonococcus complement-fixation test, one essential stands paramount, namely, the absolute standardization of all substances entering into the reaction, and this applies more particularly to the gonococcic antigen, because of its greater instability owing to watery extraction, than to the alcoholic syphilitic extract.

An important feature of the complement-fixation reaction in gonococcic infections is the necessity of employing a polyvalent antigen, owing to the apparent diversity in the various strains of the gonococcus. Thus we have utilized in our studies mono-, tri-, hexa-, and nonavalent antigens, prepared by washing off in sterile distilled water forty-eight-hour-old cultures of gonococci grown on blood agar; these suspensions were shaken for one hour, autolyzed for twenty-four hours in a thermostat at temperature of 37° C., and heated in a water bath at 60° C. for one-half hour. Before use, these antigens are diluted 1:10 by the addition of 0.85 per cent salt solution.

Although a negative reaction may be erroneously contradictory, a positive result is most reliable, in fact, more specific than the Wassermann, since thus far we have discovered no alien infection capable of producing a positive result, nor have we found any drug (as mercury in the treatment of syphilis) influential in negativing a positive reaction. These facts naturally and early suggested the advisability of comparative studies, using non-specific with the specific antigens in the performance of these serological reactions. Accordingly, polyvalent antigens were prepared from various non-gonorrhœal gram-negative and positive bacteria; namely, the micrococcus catarrhalis, the diplococcus meningitidis, the streptococcus pyogenes, the pneumococcus lanceolatus, the micrococcus albus and aureus, the colon bacillus, and the cornybacterium pseudodiptheriæ.

The technique which we have employed with the greatest satisfaction is essentially that used in the performance of the Wassermann reaction, substituting merely a specific gonococcic or non-specific antigen for the syphilitic lipotropic antigen, always using the accurately standardized single-complement unit, the required inactivations and the routine standardization of antigen, hæmolytic amboceptor, and suspension of sheep's red blood-corpuscles. A detailed description of the fundamental serological principles involved in complement fixation or deviation will be omitted. A study of the accompanying table will, it is believed, serve to give a comprehensive understanding of the technique and actual steps of the routing performance of the reactions.

Reviewing the results of our work to date with especial reference to a study of specific versus non-specific antigens to be reported in detail in a later communication, we have deduced the following facts:

1. Very rarely have polyvalent antigens prepared from meningococci, pneumococci,

[2] "The Gonococcus Complement-Fixation Test and Analysis of Results from its Use."

[1] Read before the Philadelphia Genito-Urinary Society, January, 1914. Received for publication, January 31, 1914.

TABLE OF TEST REACTIONS

	No. Test Tube	Antigen (Dilution 1:10)	NaCl Solution (0·85%)	Patient's Serum (Inactivated)	Known Positive Serum (Inactivated)	Known Negative Serum (Inactivated)	Complement (Dilution 1:10)	Incubation at 37° C. in water-bath for one-half hour.	Hæmolytic Amboceptor (Antisheep) (Titre = 1:2000) (Dilution 1:1000)	Red Blood-Corpuscles (Sheep's 5% washed suspension)	Incubation at 37° C. in water-bath for three-quarters of an hour.	Results (immediately or morning after refrigeration)	Objects of the Reactions
		cc.	cc.	cc.	cc.	cc.	cc.		cc.	cc.			
Tests for Antigen Standardization and Controls	1	0.5	1.5		0.1		0.4		1.0	1.0		Incomplete hæmolysis	To determine quantity of *antigen* to be used in test proper.
	2	0.1	1.4		0.1		0.4		1.0	1.0		Partial hæmolysis	
	3	0.2	1.3		0.1		0.4		1.0	1.0		No hæmolysis	
	4	0.3	1.2		0.1		0.4		1.0	1.0		No hæmolysis	
	5	0.2	1.3			0.1	0.4		1.0	1.0		Complete hæmolysis	To prove that the antigenic dose is not in itself anticomplementary.
	6	0.4	1.1			0.1	0.4		1.0	1.0		Complete hæmolysis	To prove that twice the antigenic dose is not in itself anticomplementary.
	7	0.6	0.9			0.1	0.4		1.0	1.0		Incomplete hæmolysis	To prove that thrice the antigenic dose is not in itself completely anticomplementary.
Tests for Complement Standardization	8	0.2	1.3				0.2		1.0	1.0		Incomplete hæmolysis	To determine quantity of *complement* to be used in test proper.
	9	0.2	1.2				0.3		1.0	1.0		Incomplete hæmolysis	
	10	0.2	1.1				0.4		1.0	1.0		Complete hæmolysis	
	11	0.2	1.0				0.5		1.0	1.0		Complete hæmolysis	
Tests and Controls for the Suspected Serum	12	0.2	1.3	0.1			0.4		1.0	1.0		No hæmolysis (Positive reaction = 1 unit)	To determine quantitatively the degree of complement fixation.
	13	0.2	0.9	0.1			0.8		1.0	1.0		No hæmolysis (Positive reaction = 2 units)	
	14	0.2	1.3	0.1			0.4		1.0	1.0		Complete hæmolysis (Negative reaction)	Shows that there was no immune body present in the patient's serum with the aid of the antigen to fix the complement.
	15		1.5	0.1			0.4		1.0	1.0		Complete hæmolysis	Proves that the immune body itself will not fix complement.

streptococci, staphylococci, colon bacilli, or cornybacteria sufficed to fix complement. This does not jeopardize the specificity of the gonococcus antigen, since it is explained on the basis of supervention of a mixed infection.

2. In ten per cent of sera examined a weakly positive result was obtained with polyvalent micrococcus catarrhalis antigen; in these cases the reaction was much more marked with the various gonococcic antigens. Thus it may be inferred that the association between the gonococcus and the micrococcus catarrhalis is not positively and absolutely defined; and it is not unlikely, on the one hand, that a culture of the M. catarrhalis is occasionally included in a supposedly specific polyvalent gonococcus antigen, while on the other it is undoubtedly true that a mixed infection, often due to the M. catarrhalis, exists in patients suffering from gonorrhœa and its complications.

3. A negative gonococcus fixation test does not necessarily mean that the patient is not infected with the gonococcus; in a primary uncomplicated acute case we have never observed a positive reaction prior to the sixth week, nor have we obtained positive reactions where the anterior urethra or vagina alone were involved.

4. A positive result apparently is more specific than the Wassermann reaction, since thus far we have found no diseases other than

gonorrhœal in which a positive result was obtained.

5. A positive reaction has been discovered in 21 per cent of patients supposedly clinically cured; such patients, therefore, should not be discharged from treatment or observation until a negative response is obtained, provided the patient has not been the recipient of immunotherapy.

6. Thirty-three per cent to seventy-five per cent of patients with chronic posterior urethritis, prostatitis, and seminal vesiculitis, with recurrent exacerbations, demonstrate a positive reaction.

7. Sixty-six per cent of all stricture cases have shown a positive result.

8. Approximately one hundred per cent of cases of active epididymitis or arthritis, at least by the fifth week, have demonstrated a positive gonococcus complement-fixation reaction.

9. The test has proved of value in gynecology in the differential diagnosis of various pelvic inflammatory diseases from one another and from neoplastic formations; also in the differentiation of certain acute and chronic arthritides.

10. Sociologically, the gonococcus complement-fixation test seems destined, along with the Wassermann, to play an important rôle in the future in determining the matrimonial fitness of candidates.

NOTES ON VESICO–UTERINE TRANSPOSITION[1]

By THOMAS J. WATKINS, M. D., Chicago

MY experience with the operation of vesico-uterine transposition dates from January 28, 1898,[2] since which time approximately 275 cases have been operated upon. Difficulties which have been encountered in an effort to follow these patients make impossible a satisfactory report on the present condition of more than 104 cases.

There has been no recurrence of cystocele in any of the cases. Thirteen of the patients have had some recurrence of the uterine prolapse. This recurrence has consisted in protrusion of the fundus uteri or of the cervix. In two cases where the uterus was senile and very small, the fundus and cervix have appeared at the vulvar orifice. These partial failures can be easily remedied by a secondary operation. In each instance these recurrences were apparently due to faulty judgment. The operation was not modified to meet the requirements of the individual case.

These modifications will be included under (1) Important features in technique, (2) Excision of parts of the uterus.

[2] Am. Gynec. & Obst. J., 1899.

IMPORTANT FEATURES IN TECHNIQUE

A. *Blunt dissection with scissors.* Blunt dissection with scissors is of much service in separating the vaginal mucosa from the bladder and the bladder from the cervix, as well as in separation of the vaginal mucosa from the rectum in performing perineorrhaphy. With a little care the plane of fascia between these structures is easily found, and thereafter the dissection is readily done in tissues almost free from hæmorrhage. In case difficulty is encountered in finding the plane of fascia, a short longitudinal incision will expose it.

B. *The transverse incision.* The transverse incision in front of the cervix should be freely made to facilitate delivery of the uterus and favor free backward and upward replacement of the cervix when the fundus is anteverted. All bleeding vessels should be ligated at this time as they are not easily accessible after delivery of the body.

C. *Incision of the peritoneum.* After the bladder has been separated from the cervix by blunt dissection, a long narrow retractor is inserted to elevate the bladder and expose

[1] Read before the American Gynecological Society, Boston, May 20, 1914.

the peritoneum. The vesico-uterine fold of peritoneum is now readily grasped with tissue forceps and incised.

D. *Delivery of the body of the uterus.* In delivering the uterus the fundus should be brought out first, as the diameters of the fundus are much less than of the anterior wall of the uterus. If the uterus is very large or the case is complicated by fibroids or disease of the adnexa, median longitudinal section through the anterior wall of the cervix and lower uterine segment will facilitate incision of the peritoneum and delivery of the body of the uterus.

E. *Excision of parts of the vaginal flaps.* The hypertrophied mucous membrane that is frequently found near the urethra should be sufficiently excised to prevent subsequent protrusion. Enough of the vaginal flaps should be excised to dispose of redundant tissue, but enough must be left to allow approximation without tension. The anterior lip of the cervix is now amputated.

F. *The suture.* The first suture should be so placed that the hernial opening of the bladder will be obliterated by the transposed uterus. If an urethrocele is present, the suture should be passed through the vaginal flaps so that when tied it will draw and hold the urethra in its normal location. Before tying the first suture the uterus is reposited sufficiently to avoid strangulation. Careful observation will show the presence of considerable submucous connective tissue, which, if included in the suture, adds another layer to the already firm wound surface. Inclusion of the uterine or cervical tissue in each vaginal stitch as suggested by Wertheim,[1] materially lessens the danger of a recurrent prolapse.

The transverse vaginal incision should usually be closed longitudinally, to lengthen the anterior vaginal wall. A complete circular incision about the cervix, as advocated in my original paper, will permit insertion of the suture so as to further displace the cervix upward and backward, and is useful when the vagina has become much shortened.

Complete hæmostasis is essential; low-grade infection by vaginal bacteria follows any considerable retention of wound secretion.

[1] Arch. f. Gynäk., 1914. cii, 201.

G. *Perineorrhaphy.* The ultimate success of the entire operation depends largely upon how efficiently the perineum is repaired. The perineal repair should extend to the upper border of the levator ani, and should include as much of the pubic portion of this muscle as is possible without too much tension upon the sutures or excessively narrowing the vagina.

MODIFIED TECHNIQUE

I. *Excision of part of the body of the uterus.* This should be done whenever the uterus is very large. The excised portion should consist mostly of the anterior uterine wall. Certain cases should include some of the fundus. Enough of the posterior uterine wall should be left to close the hernial opening through which the bladder protrudes. The length of the remaining portion of the uterus should be sufficient to prevent traction upon the cervix and shortening of the vaginal canal when the wound is closed.

II. *Amputation of the cervix.* This should be done when the cervix is much hypertrophied, and especially when very long and protruding through the vaginal orifice.

III. *Excision of entire uterine mucosa.* In cases where much of the uterine body or cervix is excised, the operative technique is simplified by excision of the entire uterine mucosa. Most of the cervical tissue can easily be excised and then the closure of the wound will materially shorten the broad ligaments. After the mucosa is excised, the uterine and vaginal wounds are very satisfactorily closed by one tier of figure-of-eight sutures.

AFTER-CARE

Many of the cases require the use of a catheter for two or three days, and occasionally as long as they are confined to bed. Early getting up in these cases is advisable. Elevation of temperature sometimes results. In these cases the head of the bed is elevated and moist dressings are kept over the vulva. The fever disappears soon after the escape of some decomposed serosanguinous discharge.

A considerable number of cases have some vesical irritation for two or three weeks. In only one instance has this bladder disturbance continued. The complication may be the

result of catheter cystitis, but is usually a continuation of the vesical symptoms that antedated the operative treatment.

CONCLUSIONS

1. Vesico-uterine transposition should be made before much protrusion through the vaginal orifice results, as the prolapse rapidly increases after this takes place; the more the prolapse, the greater the dangers of recurrences following the operation.

2. Vesico-uterine transposition cures cystocele — the most important pathological feature.

3. An occasional recurrence of the uterine prolapse will occur, except in cases where the vaginal canal can be practically obliterated. This recurrence, however, is not serious, as it is easily remedied.

4. The operative technique should be adapted to each individual case.

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DEPARTMENT OF TECHNIQUE

THE RÖNTGEN DIAGNOSIS OF DUODENAL ULCER [1]

A Comparison of the Direct and Indirect Methods

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A RECENT paper by Dr. R. D. Carman on "The Radiologic Signs of Duodenal Ulcer"[2] has seemed to the writers an insufficient expression of the present status of the röntgen diagnosis of duodenal ulcer.

Carman reports 198 cases of duodenal ulcer, operated on at the Mayo Clinic, all of whom had a preliminary röntgen examination. Out of this large number he was able to make a definite diagnosis of duodenal ulcer in only 135 cases. In other words, the failures of positive diagnosis amounted to approximately 32 per cent. The published work of Cole and of the writers does not show such a large percentage of diagnostic failures when the modern direct method of duodenal diagnosis has been used.

In order to explain better our position in this matter, we shall briefly outline the development of the present two schools of röntgen bismuth study, especially as related to the diagnosis of duodenal ulcer. The pioneers in this work, who were largely Germans and Austrians, were forced by the necessities of their clinics to depend upon the fluoroscope almost entirely. As a result, the early fundamental work was based upon signs and findings that could be brought out largely by fluoroscopic study. In consequence, the basis of diagnosis gradually developed into what might be called "symptoms-complex"; that is, a number of fluoroscopic signs largely of a functional nature were grouped together, and upon them diagnoses were founded. Among these signs were exaggerated or lessened peristalsis, antiperistalsis, increased or diminished emptying-time of the stomach, spasm, six-hour gastric residue, pressure-tender points, etc., as well as the clinical history. This method of study is the *indirect* method of bismuth diagnosis.

As a result of this study, much valuable data was obtained, and great progress was made in the diagnosis of surgical conditions of the gastro-intestinal tract. It has been found, however, that this method of study, especially when applied to the pyloroduodenal region, is frequently inadequate. Many cases may be classed as negative, which might yield positive pathological data if a more careful method of investigation were used. That is to say, errors of diagnosis are not so much errors of commission as errors of omission. In consequence, many investigators, especially Americans, have felt that a more careful study of the above-mentioned region was necessary to detect these overlooked cases.

The meal which had been used by the Continental observers, and which is still used by most of them, was the standard Rieder meal. This consists of 40 gm. of bismuth subcarbonate in about 300 ccm. of cooked cereal. Later this was modified to contain an equivalent amount of barium sulphate. Thousands of observations have been recorded at different clinics with this meal, and naturally much valuable data was accumulated. This meal, however, was too coarse and stiff to satisfactorily fill out the duodenum long enough to allow it to be observed directly. Gradually the experience of many röntgenologists led them to the use of artificially prepared buttermilk. This was desirable, not only because it very easily filled out folds and crevices in the parts to be examined, but it was easily obtainable, quickly prepared, and quite palatable. Incidentally, it was found that the bismuth meal was kept in a liquid form, with buttermilk, for a much longer time throughout the intestinal tract than by previous meals. As a consequence, the constant demonstration of the appendix, among other conditions in the right lower quadrant, was made possible.

It was found necessary with the improved meal to use two to three times the amount of bismuth contained in the Rieder meal. The writers, for instance, have used 90 to 100 gm. of bismuth subcarbonate in a mixture of 500 ccm. of artificially prepared buttermilk and water. As a result of the marked variation of bismuth it is impossible

[2] J. Am. M. Ass., 1914, lxii, 980.

[1] Read in part at the opening meeting of the Röntgen Society of New England, Boston, May 6, 1914.

to use the same functional data for diagnosis. That is to say, conclusions drawn as to rapidity of emptying, six-hour gastric stasis, position of the head of bismuth in the colon at six hours, etc., must be entirely disregarded.

This is a point which has not been properly appreciated by many röntgenologists. They have used various kinds of meals,— not only buttermilk, but malted milk, plain milk, water, mashed potato, etc.,— and have varied the amount of bismuth or barium, and yet have attempted to apply to their work the conclusions based upon the observation of functional disturbances in thousands of cases done under the Rieder technique. Obviously, this is incorrect. The only proper course left for one who wishes to use these functional data is to accumulate a large number of cases, done with more satisfactory mixtures, and check them up with operative results. This has been done, it is true, by Carman with his tremendous clinical material. He undoubtedly has a right to draw certain conclusions as to motility of the stomach and intestines with his technique. However, as we have stated above, his results with duodenal ulcer (32 per cent errors) do not warrant placing any reliance upon this indirect or inferential method as a dependable basis for the positive diagnosis of this condition.

The opposite school which has developed may be called the school of *direct* diagnosis. It is the morphological school. Its object is not to study the secondary or indirect manifestations of an organic lesion, but to demonstrate, if possible, the actual anatomical lesion itself. We have found by experiment that buttermilk mixtures are best suited for such study.

This method of diagnosis, when applied to the problem of duodenal ulcer, has yielded results of a positive nature that have not been reached by indirect methods in the hands of any investigators. Indeed, the European observers have been frank to admit that the positive diagnosis of duodenal ulcer by means of the röntgen ray is still an impossibility. Holzknecht and Haudek, in their last published work,[1] confess that they are "satisfied in the doubtful cases with a diagnosis of 'peripyloric' ulcer, without attempting a differentiation between post-pyloric and pre-pyloric ulcers."

The published results of work done by Cole and by the writers have certainly given sufficient basis for our contention that the direct method of study of duodenal ulcer will yield a far greater percentage of correct diagnoses than the indirect.

We shall now consider, in somewhat more detail, the data upon which the indirect method of diagnosis has been based. We shall follow the signs as outlined by Carman, partly because his report contains the largest number of operated cases with röntgen control that has ever been published, and partly because his study of the indirect data is as careful a presentation of this method of diagnosis as has appeared. He divides the röntgen signs into "major" and "minor" groups. His "major" signs consist of increased gastric peristalsis, six-hour bismuth residue, and a demonstrable diverticulum of the duodenum.

Gastric hyperperistalsis is a sign that has been emphasized more than any other as a dependable basis for the röntgen diagnosis of duodenal ulcer. As we have already stated in an earlier paper,[2] "abnormally marked peristalsis is an important sign if it is found." The difficulty is that even with Carman's large series of cases it was present in only 57 per cent of his proved cases of duodenal ulcer. It can undoubtedly be produced by other conditions than duodenal ulcer. Among these are pyloric stenosis due to other causes, such as early carcinoma, and also abnormal nervous influences. We have certainly seen most violent hyperperistalsis at times in individuals with no organic disease present. We believe this is a very treacherous basis upon which to found a diagnosis of duodenal ulcer. Its presence is merely suggestive, and its absence certainly does not warrant a negative diagnosis.

Six-hour bismuth residue in the stomach depends to a large degree, as we have already stated, upon the character of the bismuth meal used. Undoubtedly, the large number of röntgen examinations made by Carman has enabled him to attach a definite significance to the presence of six-hour stasis with his particular meals and technique. However, he found this residue in only 36.3 per cent of his cases of duodenal ulcer. This corresponds fairly closely with the observations of many other investigators. Indeed, Holzknecht and Haudek [3] found this residue in only 20 per cent of their duodenal ulcers. Thus we see that, at the very best, about two-thirds of the cases will give us no positive information as regards this particular diagnostic point.

The *diverticulum* of the duodenum, so-called, is undoubtedly important if it is present. Carman found it in only two cases out of 198. The writers have seen this condition in about six cases. Its rarity does not enable it to be depended upon as a constant factor in diagnosis. Inci-

[1] Holzknecht and Haudek, Fortschr. a. d. Gebiete d. Röntgenstrahl., 1914, xxi, 636.

[2] George and Gerber, Am. Quart. Röntgenol., 1913, iv, 187.

[3] Loc. cit., p. 636.

dentally we do not believe that this diverticulum is due at all to penetrating ulcer, in the sense that "Haudek's niche" is produced by penetrating gastric ulcer. Such a penetration is extremely rare with duodenal ulcer. In our experience these diverticula have been caused by the pull of adhesions for a considerable length of time, which finally resulted in the production of small sacculations. Sometimes also such sacculations may be the result of a cicatrizing process which involves all the duodenal cap except one small section in which the bismuth remains (Fig. 11).

We must therefore conclude, in regard to these so-called "major" signs, that the one which is considered most valuable, gastric hyperperistalsis, leaves us without any help in at least 43 per cent of cases. The combination of hyperperistalsis and six-hour residue, although found in only 24.7 per cent of his cases, is, according to Carman, "worth more than 95 per cent in the diagnosis of duodenal ulcer." This statement, on the face, of it seems hardly compatible with his statistics.

Again, he states that "the combination of hyperperistalsis and six-hour residue or a diverticulum, when found in an otherwise normal stomach, constitutes about the only evidence on which a purely radiologic diagnosis of duodenal ulcer may safely be advanced." If this be true, then in at least 75 per cent of cases a purely röntgen diagnosis is impossible. The results of the direct method certainly do not support this statement.

As a matter of fact, we do not feel that these alleged "major" signs are of any value as dependable aids for positive diagnosis in every instance. This is the conclusion that must be drawn from Carman's own published statistics.

When we come to the study of what he calls the "minor" signs in röntgen diagnosis, we certainly agree with him as to their relatively inferior value in all but one instance, which we shall consider at the end.

Hypermotility of the stomach is a sign which we agree is by no means pathognomonic of ulcer, since it occurs in achylia gastrica, carcinoma, and various motor neuroses. In duodenal ulcer, as we have explained in a previous publication, the presence of hypermotility results from a balance which exists between the physiological tendency towards rapid emptying of the stomach from duodenal irritation on the one hand and the mechanical obstruction from the cicatrized portion of the duodenum on the other hand. The results are so confusing that they offer no basis for definite conclusions to be applied to any particular case.

Hypertonus of the stomach, the presence of *pressure-tender points*, and the *lagging of bismuth* in the duodenum are undoubtedly all minor signs in the röntgen diagnosis of duodenal ulcer. No one of them gives any pathognomonic evidence, and any strict reliance upon these signs is certain to lead to errors of diagnosis.

When, however, we consider the last "minor" sign, namely, *deformity of the outline of the duodenal cap*, we feel that we must emphatically protest against including this among minor signs. There has been already too many loose statements about irregularity and deformity of the duodenum, and their value in the diagnosis of duodenal ulcer. The word "irregularity" does not convey sufficiently the idea as to just what we are attempting to demonstrate by the direct study of these cases. What we try to show in every instance is either a normal duodenum or the exact size, extent, and character of the actual duodenal ulcer. The entire problem revolves about the method of study of the duodenum.

In the application of the röntgen ray to surgery generally, the development has always been along the lines of attempting to get real positive data and eliminating all bases for diagnosis that were uncertain and indefinite. This trend is seen already in the röntgen study of fractures, of bone diseases, and of renal calculi. The same point of view is equally true when applied to duodenal ulcer. The only basis for definite opinion should be the actual demonstration of a normal or an abnormal duodenum. The direct school of röntgen diagnosis disregards all the indirect, so-called, "major" or "minor" signs, and restricts itself to one problem; namely, the attempt to demonstrate adequately the anatomical condition of the duodenum and the determination as to whether the duodenum so demonstrated is normal or pathological. This problem is largely one of careful and exact technique.

The fluoroscopic method, when applied to the study of duodenal ulcer from this strict point of view, is entirely unsatisfactory. It is true that sometimes the duodenum can be seen in its entirety, but it can never be seen for a long enough period of time to satisfy one as to its anatomical completeness; and it certainly cannot be shown in all cases. In the standing position, in which the fluoroscope is ordinarily used, this demonstration is usually impossible. All that can be shown is the jet of bismuth into the cap, which is speedily emptied.

It is only with the plate method, carefully carried out, that the duodenum can be demonstrated in its entirety. We do not for a moment

mean to infer that the fluoroscopic study of the gastro-intestinal tract is worthless. The fluoroscope undoubtedly has its valuable applications in the study of the stomach and many other parts of the alimentary tract. However, when it comes to a study of the duodenum and the problems involved in duodenal ulcer, the fluoroscope must really be considered as of little value.

Serial röntgenography is really the ideal way of studying these cases, but it is not necessary always to take an extremely large number of plates; only enough plates need be taken as will convince the investigator of either the normal condition of the duodenum or its constant abnormal condition. No set rules can be given as to the position of the patient during examination. All the positions — prone, standing, and lateral — may have to be used in order to obtain the desired information. The exact procedure to be followed must be worked out in each individual case as it goes along. This requires the use of rapid developers and the development of plates constantly during the course of the examination. Of course this is a more troublesome process than the indirect method, but the more accurate results obtained are certainly worth the slight extra trouble and expense.

The writers were the first to emphasize the value of the *lateral view* in the study of the duodenum. We believe that this is the most important single method known that will adequately demonstrate the duodenum every time. The technique is very simple. The patient lies on the right side, upon a small plate with an intensifying screen. The rays enter the left side of the patient. It is advisable to use the smallest cone and diaphragm obtainable, and the cone must be placed almost in contact with the left side. The length of time of the exposure depends upon the size of the patient. In general, it should be about twice as long as is necessary to obtain a satisfactory plate of the same patient in the prone position.

With this technique not only the first portion of the duodenum, but the descending duodenum, and in many instances the transverse portion, are readily brought into view (Fig. 2). In well-nourished persons this position is the only one that will bring out the first portion of the duodenum satisfactorily. These people usually have the steer-horn type of stomach, with the pylorus and duodenum held over to the right, behind the antrum. These regions are not brought well into view when plates are taken, or fluoroscopic examination is made, in either the prone or standing positions.

Likewise, the lateral position is of value in those cases where there is pylorospasm. Here the force of gravity is added to the peristaltic force of the stomach, and the weight of the meal will relax the spasm and enable the duodenum to be well filled out. This sometimes may require an hour or more to wait, and in rare instances may even require a repeated examination on another day; but at some time the spasm will relax and the duodenum will fill out. This renders possible an opinion as to whether a spasm is the result of duodenal ulcer or not.

We will briefly outline our position as regards the direct demonstration of duodenal ulcer. In the first place, 95 per cent of all duodenal ulcers, as is well known, occur in the first portion of the duodenum. Therefore, careful anatomical study of this part, as outlined with bismuth, affords us the opportunity of studying the great majority of ulcers. The smaller group, which is found in the descending and transverse portions of the duodenum, likewise give röntgen signs which are quite definite.

The first portion of the duodenum, as we have frequently maintained, has a very constant anatomical structure. It always has a regular contour and smooth mucous membrane, unless there is actual disease present. This anatomical constancy is seen in the definite bismuth picture which is obtained of the "duodenal cap." This cap shows a smooth outline, more or less triangular or elliptical in shape (Fig. 1). There is no trace of the serrations due to valvulæ conniventes, such as are found in the descending and transverse duodenum. This normal cap can be found and demonstrated in every normal individual. There is absolutely no exception to this statement. We have shown a characteristic cap even in a nine-days-old infant.

Many röntgenologists have believed that the characteristic normal duodenal cap could not be demonstrated every time in normal persons. This failure is due in every instance to either improper bismuth mixtures, improper technique, or both. The Rieder meal, we know, will frequently fail to show this cap. Buttermilk will always fill it out, if normal, at some time during the examination. In many cases, especially in the steer-horn stomachs, as above mentioned, the duodenum will not come into view in either the prone or standing positions. In such cases the lateral view is especially helpful. If buttermilk is used and the lateral position is applied, the cap can be demonstrated in every instance if the duodenum is normal and if enough plates are taken. We must repeat, there is no exception to this statement.

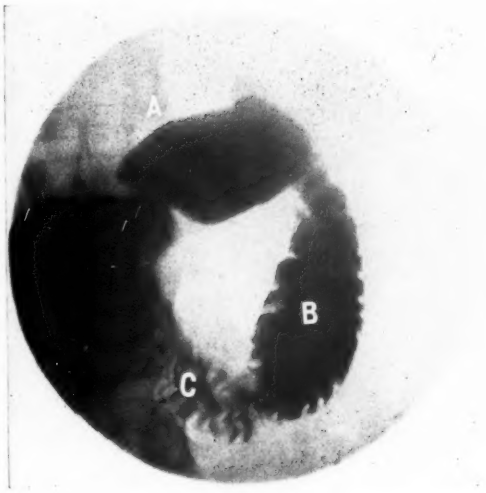

Fig. 1. Normal duodenum in a thin woman. Proved by operation for other purposes. (Operation by Dr. Godfrey Ryder.) A, first portion of duodenum. B, descending duodenum. C, transverse duodenum. Note the varying character of the three portions.

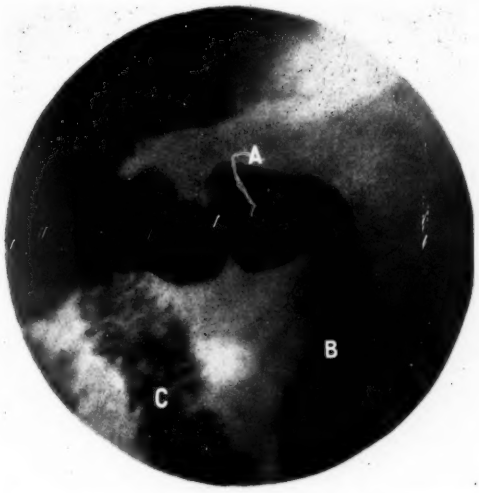

Fig. 2. Lateral view of normal duodenum in a man weighing over 200 pounds. The three portions of the duodenum are seen almost as clearly as in Fig. 1.

As a result, any defect or deviation from this outline, if found constantly on a number of plates, can be regarded as a pathological condition. Sometimes the characteristic deformity, due to duodenal ulcer, is so striking as to be unmistakable. At other times the distortion may be deceptive. The only feature that must be insisted upon is the constancy of the deviation from the normal contour. One plate showing a definitely normal cap rules out the possibility of indurated ulcer here, even though all the other plates show apparent abnormalities.

Spasm is one of the big sources of error. With spasm, however, we do not obtain the characteristic ulcer deformity. Instead there is usually a very incomplete filling of the cap, varying from one plate to another. At some time during the examination, especially with one of the lateral views, a normal cap will be obtained.

Pressure from other organs, or from abnormally placed blood-vessels, will sometimes distort the cap; but it will always be smoothed out in some one of the positions.

When gall-bladder adhesions are present, the cap will usually be completely filled out, but fixed to the subhepatic region. The fixation of the duodenum and antrum is especially demonstrable by manipulation under the fluoroscope. Sometimes the cap will show the definite serrations due to the pull of these adhesions. Again, the enlarged gall-bladder, especially when filled with stones, may leave a concave impression on the duodenum. In some cases evidence of gall-bladder adhesions will be present together with the deformity of the duodenal ulcer. These cases are often confusing. Small adhesions from the gall-bladder or liver may be overlooked, but the ulcer deformity is practically always recognizable.

The duodenal ulcers themselves usually show a characteristic bismuth deformity of the cap on one side, with an incutting on the other side very similar to the "incisura" seen with gastric ulcers (Fig. 5). Dr. William Mayo[1] has carefully studied the pathology of a number of excised duodenal ulcers. He found that in these cases the characteristic and striking process present was a very abundant connective-tissue formation in the deep layers. This cicatrix is always out of proportion to the minute mucosal defect which is usually present. It is just this disproportionately big cicatrix that we demonstrate by its effect in deforming the contour of the bismuth mass. Recently, in an increasingly large proportion of these cases, we are beginning to show not only the effect of these cicatrices, but the actual mucosal defect itself, small as it is. When careful plates are taken, especially in the lateral position, a tiny stream of bismuth can be fre-

[1] Mayo, Ann. Surg., 1913, lvii, 691.

Fig. 3. Normal duodenal cap in a patient who proved at operation to have tuberculous peritonitis. (Operation by Dr. John Bottomley.) Note the hyperstalsis, although there was no duodenal ulcer.

Fig. 4. Normal stomach and duodenum, lateral view. A, first portion of duodenum.

quently found entering the actual crater of the ulcer. We have demonstrated this actual mucosal defect in a case where it was almost of pin-point size (Fig. 6). We thus see that the direct or positive diagnosis of duodenal ulcer depends upon the actual demonstration by the plates of a characteristic deformity of the duodenum due to connective-tissue formation, and if possible the demonstration of bismuth entering the actual defect in the mucous membrane.

The negative aspect of this method of diagnosis is equally important. If a normal duodenal cap and a normal descending and transverse duodenum are shown, we feel warranted in stating definitely that there is no indurated or surgical duodenal ulcer. That is to say, we feel quite positive from the presence of these normal appearances that there cannot be any stenoses, sacculations, penetrating erosions, cicatrices, connective-tissue formation, etc. Therefore it is obvious that no chronic duodenal ulcer can be present.

At this point we are reminded of Carman's classification of the duodenal ulcers as he saw them at operation. His second and third classes consist of ulcers which have visible scar production, with more or less extensive adhesions, etc. These he will probably admit can be shown by the direct method of röntgen study. His first class consists of ulcers which "were evidently limited to the mucosa, and not seen externally because of the absence of scar tissue." According to his own admissions, however, their presence at operation was determined by the surgeon through palpation. If so, then there must have been some overproduction of connective tissue. Such being the case, we are quite positive that this class of ulcer can be demonstrated upon plates if the proper technique be used. It is just this overproduction of connective tissue that gives the characteristic deformity we have spoken of above, even though it occurs in a very slight degree. The röntgen method always exaggerates deformity, and in this instance a very small actual deformity in the duodenum might be exaggerated by the bismuth so as to give apparently a very considerable defect. This defect, however, will be of a very definite and characteristic formation, and it will be constant.

The only possible type of duodenal ulcer that cannot be shown is a kind not mentioned by Carman. This is the true simple duodenal ulcer, such as is found at autopsy with severe toxic conditions, such as uræmia or the toxæmia following a severe burn. These are truly limited to the mucous membrane, and they cannot be felt by the palpating finger from the peritoneal surface. It is only this type of ulcer that cannot be demonstrated by the röntgen ray. This, however, is not the sort of ulcer that gives symptoms; it is not the

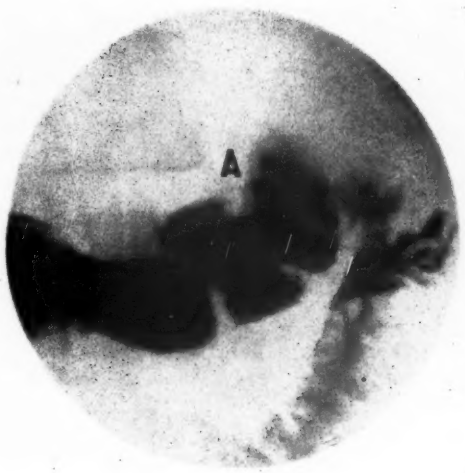

Fig. 5. A, characteristic ulcer of superior border of duodenum. (Operation by Dr. John Bottomley.)

Fig. 7. A, large ulcer of first portion of duodenum. (Operation by Dr. John Bottomley.)

duodenal ulcer with which clinicians are concerned; and it certainly is not the type with which surgeons can have anything to do. We therefore feel confident in stating that the demonstration upon plates of a normal duodenum definitely rules out the possibility of indurated or surgical duodenal ulcer.

We have now had, up to date, 82 operated cases of duodenal ulcer, all of which were previously examined by our method. This covers a period of time extending from September 1, 1912, to April 15, 1914. These operations were performed by a number of surgeons in this vicinity. Out of this number a correct diagnosis of duodenal

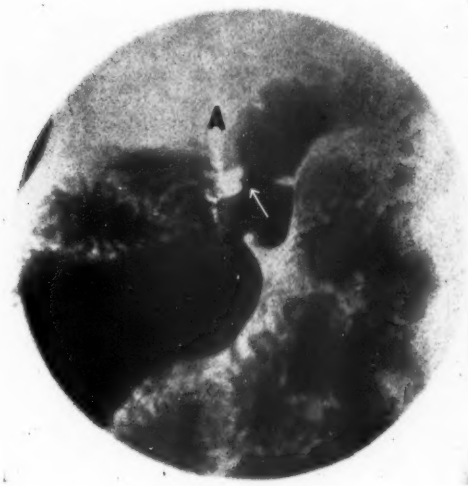

Fig. 6. A, first portion of duodenum, containing an ulcer. Arrow points to bismuth entering mucosal defect, which was of pin-point size. (Operation by Dr. D. F. Jones.)

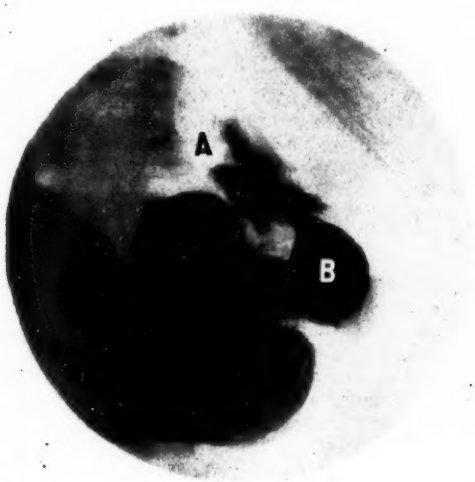

Fig. 8. A, ulcer of duodenum. B, antrum pylori. Plate taken with patient prone. Hyperperistalsis was present here.

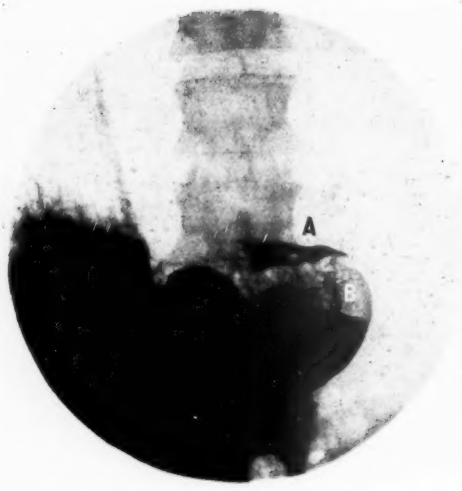

Fig. 9. Same case, standing. Shows the difficulty of filling out the antrum and duodenum, because of precipitated bismuth. A, first portion of duodenum. B, antrum.

ulcer, with its exact location and extent, was made in 78 cases. In 3 of the cases a diagnosis of duodenal ulcer was made, but there was a failure in several minor details, as follows:

CASE 1. Röntgen diagnosis was "ulcer on inferior border of duodenum and a penetrating ulcer on superior border." At operation the first ulcer was present, but the second defect was found to be a sacculation due to adhesions.

CASE 2. Röntgen diagnosis of duodenal ulcer. At operation a thickening was found in the duodenum, but no external evidence of scar was seen.

CASE 3. Röntgen diagnosis of duodenal ulcer. The ulcer was found at the pylorus, with a cicatrix extending both into the duodenum and the antrum pylori.

In one case only of the series was there an absolute failure in diagnosis. In this case the diagnosis of duodenal ulcer was made in spite of the fact that one of the lateral views showed a normal duodenum. The incomplete filling seen in the other plates was the result of a spasm probably reflex to a chronic appendicitis, which was found at operation. In this case the error in diagnosis was due not to the deficiencies of the method itself, but to carelessness in interpretation. The one single plate showing a normal duodenum is thus sufficient to overthrow any diagnosis of indurated duodenal ulcer.

As regards the negative aspect of the method, we have now had approximately 150 other operated cases, in which we had previously reported a negative duodenum. When these cases came to operation for various other conditions, in not one of them was a duodenal ulcer found. In one autopsy duodenal ulcer was found where the röntgen examination was negative.

It is thus obvious that with the direct method it is possible to achieve results in the diagnosis of duodenal ulcer, compared with which the indirect method, with its large percentage of errors in capable hands, certainly offers no encouragement. It is also certainly true that the demonstration of the actual lesion, far from being a "minor" sign, is really the one and only dependable basis for the diagnosis of indurated duodenal ulcer.

SUMMARY

In the röntgen diagnosis of duodenal ulcer two methods of study have gradually developed. These are the direct and the indirect methods of diagnosis. The indirect method, generally used by European observers, is based upon a consideration of "symptoms-complex." These are groups of signs, usually of a functional nature, which have been found associated with organic lesions.

The direct method disregards this evidence

Fig. 10. Same patient, lateral view. A, characteristic deformity due to cicatrix of ulcer, seen much more clearly than in prone position (Fig. 8). (Operation by Dr. H. H. Germain.)

entirely, and merely determines the normal or pathological condition of the duodenum. This can be done only with careful attention to technique. From this strict point of view, fluoroscopy is very unsatisfactory. Repeated plates are much more valuable. They must be taken in the prone, standing, and especially the lateral, positions; and from these plates the anatomical condition of the duodenum is determined.

A normal duodenum can always be shown if proper technique and proper bismuth mixtures are used. The demonstration of a normal duodenum, even on a single plate, rules out the presence of indurated or surgical ulcer.

Duodenal ulcers show a characteristic deformity, due to connective tissue, with often a stream of bismuth seen entering the mucosal defect.

Of 82 operated cases of duodenal ulcer an exact diagnosis was made in 78 cases. In 3 cases duodenal ulcer was reported, but there were minor errors of diagnosis. In one case there was a complete failure of diagnosis.

Of 150 operated cases in which a negative röntgen diagnosis was made duodenal ulcer was not found in any case.

In one autopsied case a duodenal ulcer was found, where the previous report had been negative.

The results of the direct method are far superior to those of the indirect method, even in the best of hands.

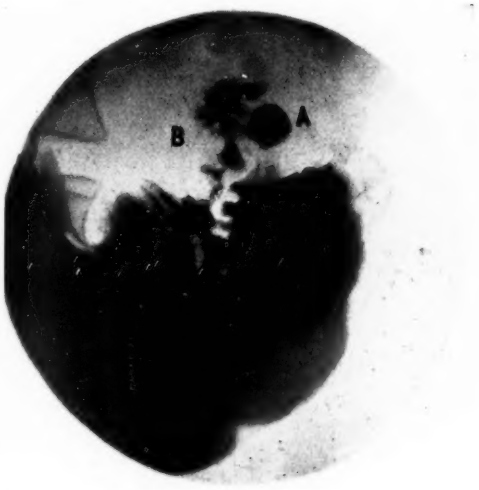

Fig. 11. A, sacculation due to almost complete obliteration of the first portion of the duodenum by cicatrix. B, descending duodenum. (Operation by Dr. A. K. Paine.)

The actual demonstration of the lesion itself is the only important factor in the diagnosis of indurated duodenal ulcer.

THE OPEN METHOD IN THE REDUCTION OF FRACTURES

By W. RUSSELL MACAUSLAND, M. D., BOSTON
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A DISCUSSION of the treatment of fractures, particularly the advancement in such treatment, is always of interest to the general practitioner, as well as to the surgeon, but probably no part of general practice is so much avoided, or at least accepted with as great hesitation. There has been a great deal written of late on fracture treatment. Many of these articles stand out as brilliant monographs, notably those of Lane, while others are recapitulations. It is, of course, impossible for me to discuss and illustrate more than certain lines of development in the treatment of fractures which I feel are of importance. We all have had certain principles in fracture treatment so thoroughly drilled into us in our school and hospital training that it is hard to accept new ideas, but with the progress of asepsis and operative technique much is being accomplished in surgery that has heretofore seemed hopeless. Within five years, surgeons have been considered radical who have intervened surgically in the treatment of simple fractures. I know, on the other hand, that many surgeons with little judgment and surgical skill have attempted the operative treatment of fractures, and, aside from frequently obtaining sepsis in the wound, have often added foreign material to suppurate later.

The method of reduction by manipulation, "closed reduction," is not without danger to vessels, nerves, and muscle, besides often not attaining the desired end; i. e., the return to proper alignment. As an illustration of this, take the usual fracture of the femoral shaft in which end-to-end apposition is rarely attained. There are out of a large proportion of fracture cases that one sees a certain percentage that have given unsatisfactory results by following this "conservative" method. It is concerning these types of fractures that I shall speak.

This small group should, I believe, as a routine, be subjected to an open incision and an anatomical reduction of the fragments. Aside from the return to proper alignment, there always should be considered the question of joint strain, as is strikingly seen in orthopedic surgery more than in general surgery. The general surgeon treats his fracture of the femur and gets union and often never sees the patient again. Years after, an orthopedist finds the patient with scoliosis resulting from a short leg. A shortening of one-half to three-quarters inch in a growing child causes joint strain, resulting in the development of structural deformities. Nevertheless, the surgeon considers one-half inch shortening a good result. Personally, I have reached the stage where I subject all fractures of the femur, except in the infant, to reduction by the open method. There has always been the dread of introducing sepsis in the open fracture wound. I can combat this point only by calling attention to the parallel reluctance of the surgeon to open the knee-joint. It has been only within the last ten to fifteen years that fractures of the patella have been subjected to operative interference as a routine, yet it has been well recognized that in order to get a true bony union in patella fractures not stellate in character, operative interference must be undertaken.

Up to the time Mr. Lane began insistently to champion the open treatment and the use of plates, strong prejudice against the open treatment of fractures existed. This was justified partly by results and partly by tradition. Strict asepsis and non-traumatic technique became recognized as all-important. A surgeon thus well founded has the moral right to treat any fracture by the open method and does not thereby add to the existing dangers. The advent of the open method may, however, bring many disastrous results unless proper asepsis has been carried out. With asepsis we can open safely a fracture and skillfully reduce it with less damage to the surrounding parts than by manipulation.

Undoubtedly, this is the greatest advance that has been made since the advent of bone-plating. I feel strongly that too many metallic splints are being used. Osteomyelitis and irritation from loose screws and metallic material in contact with bone may sooner or later occur. Just as is seen occasionally in old cases of excision of the knee in which silver wire has been used, discharging sinuses may open ten to fifteen years after the insertion of the wire. Rarely, therefore, I believe, is it necessary to plate—only in exceptional cases where position cannot be held following reduction by manipulation or open method even when held with some absorbable material; in other words, plating is the method of last resort.

Radiograms as routine should be taken before

Fig. 1. Cheever (a). Fracture seventh metacarpal shaft with fracture dislocation of proximal end of a phalanx.

Fig. 2. Cheever (b). Fracture seventh metacarpal shaft with fracture dislocation of proximal end of a phalanx. Complete reduction by incision following two previous failures of closed method.

Fig. 3.

Fig. 3. Ayash (a). Fracture both bones of forearm (several weeks old). Before operation.

Fig. 4.

Fig. 4. Ayash (b). Fracture both bones of forearm (several weeks old) after reduction by open method.

Fig. 5.

Fig. 5. Ayash. (a). Fracture humerus lower one-third. Before operation.

Fig. 6.

Fig. 6. Ayash (b). Fracture humerus lower one-third after reduction by open method. Plaster dressing.

Fig. 7.

Fig. 8.

Fig. 7. Moses (a). Fracture of upper shaft of humerus. Before operation. Two unsuccessful attempts at reduction by closed method.

Fig. 8. Moses (b). Fracture upper shaft of humerus. After open reduction. Plaster dressing.

Fig. 9. Subtrochanteri fracture of femur showing traumatic coxa vara, angle of 100 degrees, overriding. Before operation.

reduction and again through the retentive dressing within a few days after.

The technique developed in this work is, I believe, always individual. An attempt should be made to wall off the skin incision by sterile towels and clamps so that in handling the wound the skin is not touched. I see no reason why the gloved fingers should not be inserted into the wound if the operator is clean, and much muscle separation may be done with a blunt dissector and by the use of the fingers. When the fracture cavity is exposed it is wiped out with sponges and then attention is paid to fragments. If it is a simple transverse fracture, first one end and then the other is pried up into the wound and the ends are brushed off with a sponge. Care is taken not to injure the periosteum or peel it back. After the ends have been cleaned the fragments are placed in alignment, and often the serrations can be made to fit each other so that only the line of fracture is seen. One succeeding in this procedure is at once impressed with the stability of the bone when this anatomical reduction is attained. If there is a tendency to slipping, a notch made with a file will often suffice to hold properly. When there is a slanting fracture, following the above procedure, I am apt to wind with plain catgut. After alignment is obtained, the greatest care should be used to maintain the position of the fragments. This requires trained assistants, or, in femur cases, some form of traction apparatus on which the patient is placed before the operation is started and which will allow the application of plaster before removal, such as the Echol's traction apparatus. Since adopting these methods, I find myself practically abandoning the use of a bone-plate, and the results, not only as regards alignment and position, but also as regards union and function, justify the extra labor and care required by this technique. It might be well to state here that I remove all bone-plates which I have had to use, in three months' time, and hence have avoided all the unpleasant after-results sometimes seen.

The important point in the treatment of fractures is the return to anatomical alignment. Such return when not complicated by grave risks is always indicated. Union seems to occur more quickly and there is notably less callus formation by this open method.

THE RÖNTGENOGRAPHIC DIAGNOSIS OF PROSTATIC ENLARGEMENT BY MEANS OF AIR INFLATION OF THE BLADDER[1]

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AND
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THE object of this paper is to call attention to a method which we consider of value in the differential diagnosis of prostatic enlargement when cystoscopy cannot be employed. Whenever feasible, cystoscopy is to be preferred, for by this means we are enabled to obtain information which cannot be afforded by any other method. However, it is well known that cystoscopy cannot be performed in many cases in which the hypertrophy is confined mainly to the median lobe. In these instances the outgrowth may be so pronounced, and the urethra so deformed, that a profuse hæmorrhage is encountered as soon as the instrument strikes the prostatic urethra. Furthermore, cystoscopy may be impossible with a stricture of the urethra, or through a urethra with false passages. It may be inadvisable in debilitated subjects with badly infected bladders, owing to the danger of sepsis.

The method is based on the well-known fact that a medium of air or other gaseous substances intensifies the röntgen rays, rendering objects clearly visible which, in another medium, may be indistinguishable. The technique is simple: a small-sized rubber catheter is introduced into the bladder, the organ emptied, and the inflation apparatus attached. This consists of an ordinary rubber hand bulb, to which is attached a glass bulb filled with cotton in order to filter the air. The air pressure can be fairly well gauged by this apparatus. The bladder is very slowly and gently inflated until the patient complains of a sense of fullness. It is not advisable to inflate any further, for a violent and painful spasm may be produced, expelling both the air and the catheter. The catheter is then withdrawn and the escape of air from the urethra prevented. The plate and X-ray tube should be adjusted before inflation so that the exposure can be made immediately. The patient is placed in the ventrodorsal position. A compression diaphragm of six and one-half inches diameter is lightly applied in such a direction that it

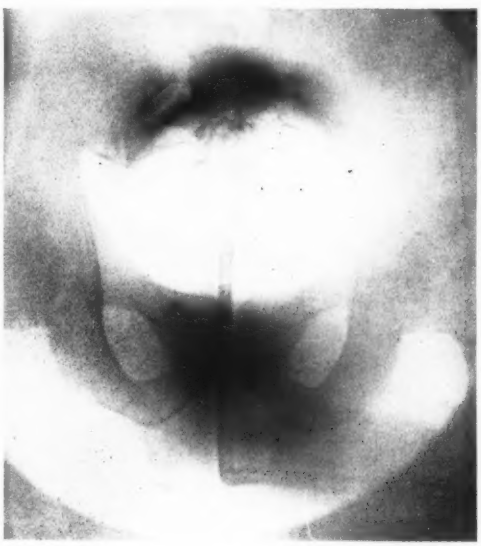


Fig. 1.

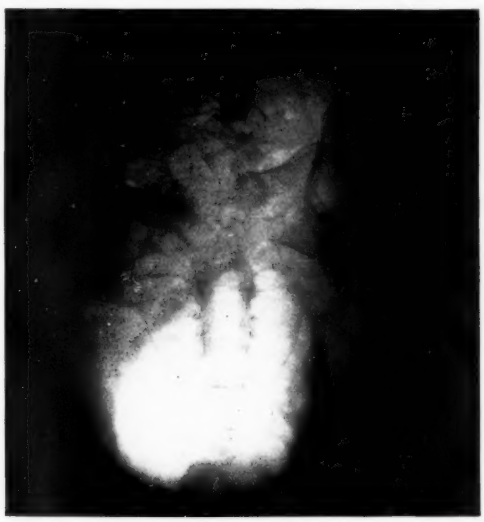


Fig. 2.

Read before the Section on Genito-Urinary Surgery of the New York Academy of Medicine February 18, 1914.

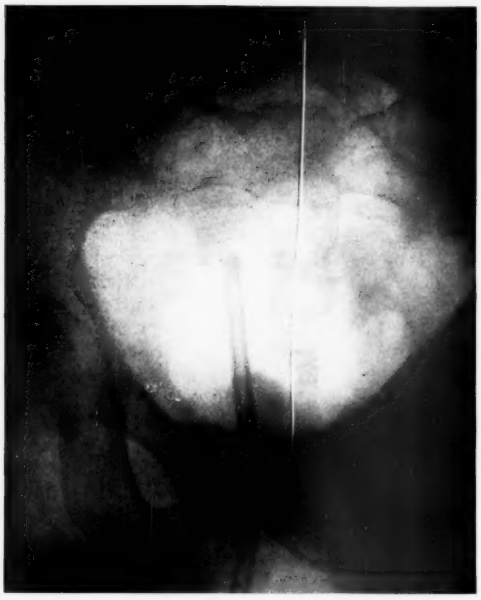


Fig. 3.

brings the focus of the tube about three inches above the symphysis pubis at an angle of eighty degrees with the plate. The radiographs show the prostatic shadows within the bladder very distinctly. That these shadows indeed represented the prostates was proven by operation in three of the cases. After we had carried out the above described method in a number of instances, an examination of the literature revealed a similar method employed some four years ago. Burkhardt and Floerchen[1] who carried out these observations made use of oxygen inflations with a rather complicated apparatus. Their results corresponded with ours, but their procedure necessitated a cumbersome outfit with no compensating advantage.

Fig. 4.

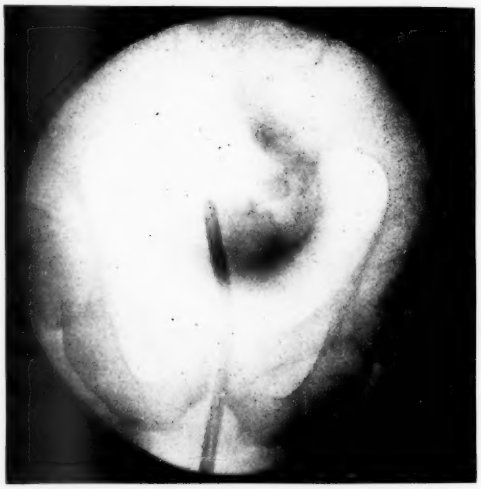


Fig. 5.

The practical advantages of the method we have employed will be evident from the short histories of the following cases:

CASE 1. Bladder with normal prostate. Patient aged thirty, showing regularity of bladder outline with no bulging in the prostatic region (Fig. 1).

CASE 2. Patient aged seventy; prostatic symptoms of many years' duration, with four ounces of residual urine (Fig. 2). No appreciable enlargement of prostate per rectum. Cystoscopy cannot be performed on account of very small meatus; patient refuses metotomy. Radiograph shows pear-shaped bladder with small median lobe enlargement.

CASE 3. Patient aged sixty-nine; with complete retention of urine. Permanent catheter retained on account of difficulty in entering bladder (Fig. 3). Cannot be cystoscoped owing to obstruction in prostatic urethra. Radiograph shows more marked intravesical enlargement than in preceding case. Confirmed at operation.

CASE 4. Patient aged seventy; prostatic history of few years' duration; moderate enlargement of prostate per rectum (Fig. 4). Radiograph shows distinct intravesical bulging of prostate. Confirmed at operation.

CASE 5. Patient aged seventy; complete retention of one week's duration (Fig. 5). Large prostate, palpable per rectum. When first seen could not be cystoscoped, owing to obstruction in prostatic urethra; subsequently cystoscoped with difficulty. Radiograph shows distinctly marked intravesical bulging of prostate. Confirmed at

[1] Burkhardt and Floerchen. Über die Darstellung der Prostatahypertrophie in röntgen Bilde. Deutsche Ztschr. f. Chir., 1910, C. V.

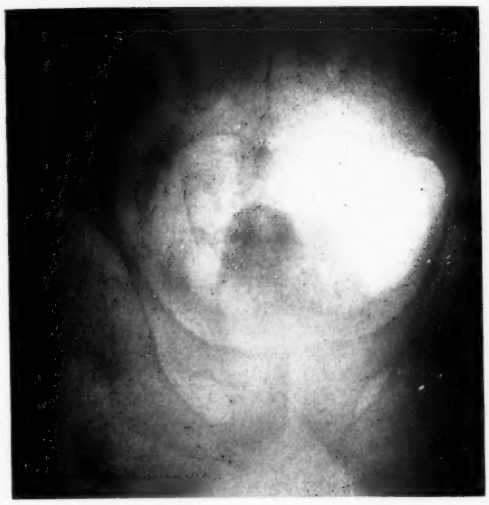


Fig. 6.

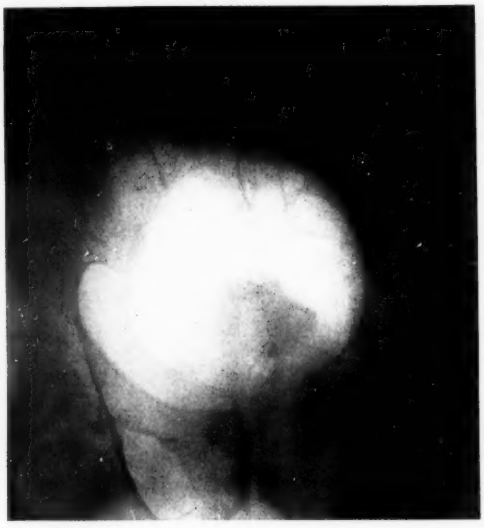


Fig. 7.

operation. Original radiograph distinctly demonstrates enlargement of entire gland.

CASE 6. Patient aged seventy-two; fourteen ounces residual urine, moderate enlargement per rectum; cystoscopy attempted a few times but cannot be performed on account of marked obstruction in prostatic urethra causing profuse hæmorrhage; radiograph shows very marked intravesical enlargement (Fig. 6).

CASE 7. Patient aged sixty-five; prostatic symptoms of six years' duration (Fig. 7). Large prostate palpated per rectum. Radiograph shows posterior urethra in which can be seen the catheter, and two large prostatic lobes which project into the bladder.

We desire to express our thanks to Dr. Beer, attending surgeon to the Genito-Urinary Department of Mt. Sinai Hospital, for having placed his material at our disposal.

WOVEN CATGUT SPLINTS FOR THE OPEN TREATMENT OF FRACTURES [1]

A Preliminary Report

By DAVID C. STRAUS, M. D., Chicago
Assistant in Surgery, Rush Medical College; Associate in Surgery, Michael Reese Hospital

ALTHOUGH some previous attempts have been made to construct an absorbable device to hold the fragments of a fractured bone in accurate apposition until healing has progressed far enough to render this artificial support no longer necessary, none of these devices have worked out practically, though the metallic magnesium bone peg [2] has been used with some success. None of the methods now in general use to directly hold the two ends of a fractured bone in apposition are ideal. Metal bone-plates (Lane, Lambotte) have perhaps proved the most successful means of directly holding the bone fragments together, but these metal plates occasionally have to be removed eventually because of their foreign-body action. All of the other recognized means of direct fixation of bone ends also leave much to be desired. Therefore, an absorbable splint of sufficient breadth to successfully grasp the bone fragments firmly, if of sufficient strength to hold them together until callus formation is well advanced, and constructed of a material, the time of absorption of which could be regulated rather definitely, would seem to be a welcome competitor in this still open field.

The writer believed that catgut, if properly prepared and suitably applied, might fulfill these conditions and conceived the idea of weaving heavy catgut suture material in the form of a closely woven mesh, and using this as a cufflike splint about the fractured bone. As the ideal sought is to do away with any permanent foreign body, the following method of applying the catgut mesh presented itself and was decided upon: to have the catgut woven in the form of a rug with long fringed ends, the rug to be just a little shorter than the circumference of the bone, and the fringed ends to be used to tie the rug about the bone as a splint. These ends when tightly tied stretch the rug about the bone, holding it firmly in place.

The idea has been carried out in a number of experiments on dogs. The splints, so far, have been made of rough, raw, German catgut No. 4 and No. 5. The raw gut has been given to an expert oriental rug weaver, who weaves it on a hand loom, the gut being wet during the process

[2] Groves, "Operative Treatment of Fractures," Lancet, Lond., 1914, i, 516.

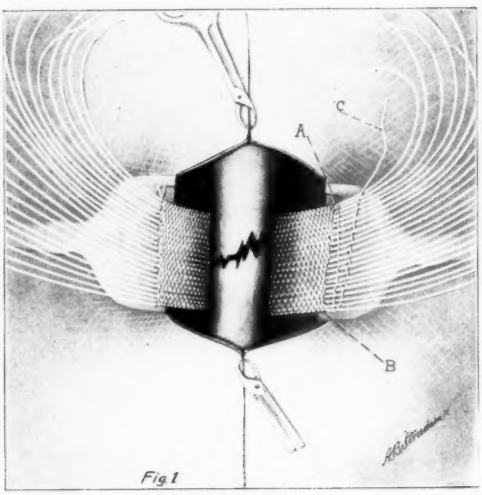
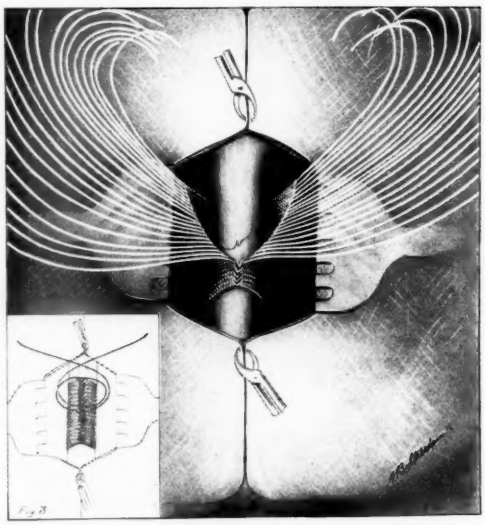


Fig. 1



[1] From the Morris Institute of Medical Research of Michael Reese Hospital; Department of Experimental Surgery.

of weaving to soften it so that it is possible to make a very closely woven rug. The rugs are long enough to encircle the femur of a large dog, and are so woven that the length of the rug can easily be reduced to exactly fit any bone of a smaller circumference. This is of great practical importance, and is accomplished by having the strands that run the long way of the rug (the warp) consist of separate fibers, while the cross fibers of the rug (the woof) are made of one long, continuous strand of gut which is alternately woven over and under the long parallel strands. To shorten the rug to fit any given bone, it is only necessary to cut one end of this cross-strand free, unravel a sufficient amount, and then tie the free end again (Fig. 1 C). Thus in human work it would be necessary to have only two sizes of rugs, one for large bones (femur, humerus) and one for small bones (radius, ulna). When the finished rug is dry, it is cut from the loom and is ready to be sterilized. So far, this has been done by the Bartlett iodine method only. Through the kind courtesy of Dr. A. D. Bevan this has been carried out at the Presbyterian Hospital. In experiments still to be carried out, various other methods of catgut preparation and sterilization will be tried, as well as other absorbable suture material, i. e., chromic catgut, kangaroo tendon, etc., to determine which is the most suitable for this purpose.

A glance at the accompanying drawings will explain how the splint is applied. The bone ends are exposed by a free linear incision and the muscles gently separated from the bone; the catgut rug is then introduced around the bone, as shown in Fig. 1, care being taken not to injure or displace the periosteum. If the splint is too long or is a little less than just surround the bone when the ends are tightly tied, one end of the cross-strand (the woof) is cut free, this end of the cross-mesh unraveled, as shown in Fig. 1 C, until the rug is short enough and then the free end is tied again, either at a point corresponding to point A or point B. Now the rug is ready to be tied about the bone. Being sure that the line of fracture is at the center of the splint, one begins tying the two opposite free ends of each of the longitudinal strands of the rug. In practice it is sometimes well to tie the first pair at one end and then the first pair at the other end of the splint, and so on, to finish by tying the strands over the seat of the fracture instead of beginning to tie at one end and continuing toward the other end, as shown in the accompanying drawing, (Fig. 2). If it seems desirable to re-enforce the splint, the free ends after having been tied as described above are long enough to make it possible, after having tied the first series of suture-ends to carry the free ends around the tied splint as shown in Fig. 3 (small figure), and tie each pair of ends again over the original row of knots, so as to thus double the thickness of the splint. However, in the animal experiments this has never seemed necessary. When all the strands have been tied and cut, the soft parts are united over the bone with No. 0 plain catgut, the fascia and skin each similarly closed, and the limb put up in a plaster cast, which is left in place for three or four weeks.

The result in the ten dogs on which this procedure has been tried have been encouraging enough to make it seem desirable to make a preliminary report of the method at this time. In a later communication, full details of the results and technique will be published. However, at this time it may be stated that with the splints as they have so far been used there is some interference with external callus formation, the only apparent external callus being just beyond either end of the splint in the form of a collar of callus; the internal and intermediary callus seem well developed. There have been three cases of non-union. One was due to local infection. The second was in a dog that died from an infected struma. The third was in a dog that contracted the mange and was killed because it was so emaciated. In these two latter cases the non-union may have been due to the intercurrent constitutional disturbance. It is too early to draw any definite conclusions, except that no trace of the splint is to be seen at the end of three weeks and no inflammatory reaction seems to be produced by the presence or absorption of the splint, except in a few cases where a serous oozing occurred soon after the operation. This ceased shortly, however, and the healing was per primam.

THE SURGICAL TREATMENT OF COMPLETE PROLAPSE OF THE UTERUS[1]

By EMIL NOVAK, A. B., M. D., Baltimore, Maryland

IT is only during the past decade or so that there has been anything approaching a crystallization of opinion with regard to the best methods of operative procedure in the treatment of complete prolapse of the uterus.

Ventral fixations of one form or another, either of the uterus or of the cervix, marsupialization of the cervix or of the entire body of the uterus, hysterectomy, partial or complete closure of the vagina, and injections of paraffin and other substances into the pelvic connective tissue are only a few of the many methods which were in former years advocated for the relief of this condition. Some of them are not yet obsolete.

By conjuring up this rather disquieting vision of the past, I do not mean to imply that gynecologists are now entirely agreed upon any one plan of treatment. We still have our pro-hysterectomists and our anti-hysterectomists, but the more bizarre forms of treatment are in the background. The undoubted advance which the past decade has brought in the results of the surgical treatment of prolapse is a sufficient explanation for the popularity of the methods responsible for this improvement. Only a small part of the advance can be attributed to a better understanding of the mechanism involved in the occurrence of procidentia. The condition is commonly looked upon as a species of hernia, but there is no generally accepted description of the steps involved in its production. In the majority of cases, the uterus is accompanied in its descent by the bladder, often by the rectum. The vagina is inverted with greater or less completeness. Sometimes the uterus in its descent slides away from the bladder, carrying only the vagina with it. Much more frequently the bladder is carried down with the uterus, producing a large cystocele. Even though the latter he large, there may be little or no rectocele, while on the other hand a large rectocele is occasionally observed when the cystocele is slight or even absent. Cases of the latter type, in my experience, are rare. In the majority of cases, of course, there is marked relaxation of the perineum, the condition usually occurring in multiparous women. Even complete prolapse of the uterus may, however, occur in nullipara, as in one of my own cases. As a matter of fact, the condition has been observed in infants.

While complete prolapse of the uterus is often allowed to persist for many years, and while the condition is not incompatible with a fair measure of health, it sooner or later, as a rule, causes distressing symptoms. Especially annoying are those attributable to the cystocele. Inability to empty the bladder without pushing it up, with retention of urine and the inevitable cystitis, are usually seen in most cases of long-standing procidentia. Aside from these urinary symptoms, the dragging pain and the irritation or even ulceration caused by friction between the protruding mass and the thighs or clothes often make the lot of the sufferer a most unhappy one.

In view of these facts, it is not surprising that in former years various more or less heroic measures have been advocated for the relief of this troublesome condition. It is not my purpose to review these operations, nor to discuss their shortcomings. Suffice it to say that up to ten or fifteen years ago the condition was generally treated by combined abdominal and vaginal operative measures, some form of uterine suspension or fixation, together with perineorrhaphy and anterior colporrhaphy, being perhaps the most popular plan of attack. While cures were effected in a certain percentage of cases — I shall not attempt to put this in figures — recurrences were frequent, and the results, taken all in all, were disappointing.

There were several reasons for this. The first, though not the most important, was the fact that the older methods of perineorrhaphy, as practiced by Emmett and his followers, took little cognizance of the proper apposition of the perineal muscles, especially the levator ani. Many of the older perineorrhaphies might be said to have been cosmetic rather than utilitarian in their results. More important than this, however, is the fact that none of the older methods of anterior colporrhaphy were effective in holding in check a bladder which persisted in pushing its way down through the anterior vaginal wall. Certainly the mere excision of an oval piece from the latter can scarcely accomplish such a result. For, whatever the mechanism of procidentia uteri, it is the cystocele which has always been the chief stumbling block to successful treatment. The cases of prolapse in which no recurrence takes place after combined uterine fixation and colpoperineor-

[1] Read at the Annual Meeting of the Medical and Chirurgical Faculty of Maryland, Baltimore, April 29, 1914.

rhaphy are usually those in which the cystocele is either not large or is absent altogether. As already stated, those cases are in the minority, and hence the unsuccessful results so often noted.

It was in an effort to overcome this tendency to bladder prolapse that an operative procedure has been developed which has created a new epoch in the treatment of this condition. The cardinal principle of this operation consists in interposition of the uterus between the bladder and the vagina. While this step represents a new departure in the treatment of procidentia, it had been already employed by Freund and others in the cure of very large vesicovaginal fistulæ, the fundus being used to close the fistulous opening. The names of a number of men are associated with the interposition operation for prolapse, more especially those of Watkins, Schauta, Wertheim, and Freund. Every operator follows his own technique in the performance of this operation, although the principle is the same with all. The effect of the procedure is to utilize the uterus as a buttress upon which to rest the bladder. In other words, instead of the uterus being above and behind the bladder, as it is normally, the bladder is made to rest upon the uterus, virtually changing places with it. By this interposition of the fundus, the bladder is carried up into the abdominal cavity, where it belongs. The hydrostatic pressure of the distended bladder is thus removed from the front of the uterus, where it exaggerates the cystocele, to the back, where it only blends its action with that of the intra-abdominal pressure to keep the fundus directed downward and forward. The cervix is of course thrown backward and somewhat upward.

The technique of the operation is so well known that I shall not describe it, except in so far as a report of my own cases may have to deal with a few aspects of the problem which are still *sub judice*. I have performed this operation in twenty-six cases of complete prolapse in the past five years, and of these I have had the opportunity of re-examining eleven at periods of from a few months to five years. I have heard indirectly from five other cases, the remainder having been lost sight of. With one exception, of which I shall speak later, the results have been highly satisfactory, the uterus having retained its new position, and the patient being free from symptoms. A considerable number of patients have complained of some dragging pain in the pelvis for a time after the operation. This is probably due to the pull on the uterine ligaments as a result of the new position of the uterus. Others have complained of some urinary irritability, obviously due to pressure on the urethra or bladder. Neither of these symptoms has persisted very long in any of my cases. A detailed report of all the cases would be neither interesting nor profitable, and hence I shall merely say a word concerning a few of them which seem, individually or in groups, to illustrate special points of interest. Of the twenty-six patients in my series, seventeen were beyond the menopause and nine were still in the child-bearing age. Of the latter group all were multiparæ. While there is usually no question as to the advisability of the operation in women beyond the child-bearing age, it is necessary, in the case of the child-bearing woman, to decide each case on its individual merits. In the case of the woman who is very desirous of having children, the Watkins-Schauta operation is at once eliminated from consideration, in which case most operators would prefer to perform some form of uterine suspension in combination with a plastic operation on the vagina and perineum. If the cystocele be large, good results are obtained from the "modified" Watkins-Schauta operation, in which interposition of the fundus is not done. On the other hand, in the case of the woman who has had perhaps a number of children, and who is suffering with extensive prolapse, the woman's sole desire is to regain her health and comfort, regardless of the possibility of future pregnancies. No other operation assures this result as does the Watkins-Schauta operation, and it seems to me to be not only justifiable but clearly indicated in such cases. Under such conditions it must, of course, be combined with sterilization of the woman, this being usually easy of performance in the course of the operation. The method I have used in the nine cases in which I have carried out this plan has been resection of an inch or more of the tubes, near the cornua, the stumps being buried in the broad ligament peritoneum.

It follows from what has been said that the wishes of the patient are entitled to consideration in the surgeon's decision as to the type of operation to be selected. If one of the less radical operative procedures be chosen, the patient should be told of the possibility of recurrence. The two principal factors to bear in mind are, on the one hand, the desire of the patient to get permanently well, and on the other, the desire for more children. The degree and character of the prolapse should also be taken into consideration, together with such factors as the patient's general condition, her station in life, etc. It will thus be seen that this problem often calls for the exercise of careful surgical judgment.

There are some operators who make a practice of routine amputation of the cervix in all cases. I do not see the logic of this, although I believe that the cervix should be removed whenever very much hypertrophied, as it so frequently is. On the other hand, when the cervix, and frequently the entire uterus, is small and atrophic, as it is so apt to be in elderly women, I can see no advantage in its amputation. As a matter of fact, it is strongly maintained by Mayo that the cervix should be retained whenever possible, inasmuch as the perineal muscles continually lift it upward, thus throwing the fundus downward and forward, after the manner of action of a pessary. Ulceration of the cervix is an indication for its removal. In my twenty-six cases, the cervix has been amputated in twelve.

In two recent cases, not included in the series of twenty-six, though starting out with the intention of performing a Watkins-Schauta operation, I decided to remove the uterus entirely, and to follow out the procedure advocated by Goffe. Both of these patients were old women, and in both the uterus was very small and atrophic, offering no support to the bladder. In one of them, in addition, the cervix was the seat of extensive ulceration, although malignancy was excluded by microscopic examination of a clipping. At any rate, the uterus was removed in both cases, the round and broad ligaments being brought together and the bladder stitched as high as possible on the combined stumps. There has been no recurrence in either case after five and three years respectively. The question of whether or not it is best to remove the uterus as a part of the operative treatment of prolapse is perhaps the one which has been more extensively discussed than any other pertaining to the entire subject. Advocates of both plans of treatment report good results. Theoretically, it seems to me that the anti-hysterectomists have the weight of argument on their side, and certainly the results of the interposition operation would be difficult to improve upon. By either plan the uterus itself is cared for, in one case by removal, in the other by its suture beneath the bladder. The matter therefore resolves itself largely into a question as to which operation takes better care of the bladder — which, in other words, more certainly prevents a recurrence of the cystocele.

A properly performed perineorrhaphy is essential to the success of this operation. The only case in my series in which an unsatisfactory result has been noted is one in which there had been a complete prolapse for fifteen years, according to the patient's history. The interposition operation was performed in the usual way. On attempting to perform the customary perineorrhaphy, however, no trace of muscle tissue could be found. The outlet was enormous, fully ten by six cm. The levator ani had apparently undergone attenuation and complete atrophy as a result of the long duration of the procidentia. The perineorrhaphy which was performed, therefore, brought together only fascial tissue. In spite of the fact that the vagina was narrowed as much as possible, the perineum soon began to yield, and the prolapse recurred, but in a manner different from the original one. The vaginal orifice again becoming very large, the uterus now came down bodily, as it were, with its long axis at right angles to that of the vagina. It still maintained its position beneath the bladder, there being no prolapse of the latter ahead of the uterus. In spite of the dropping of the uterus, the patient was materially improved, especially as concerned her urinary symptoms. This case illustrates the importance of a properly performed perineorrhaphy as an auxiliary to the interposition procedure itself.

In a number of other cases, certain minor difficulties were encountered. In one the operation was rendered difficult by the large size of a subinvoluted uterus, the operation being performed only seven weeks after parturition. The large, boggy fundus was drawn down through the peritoneal opening with difficulty, and the pressure against the bladder and urethra caused inability to void urine for a few days. Involution took place rapidly, however, and the ultimate result, four years later, is excellent. This case illustrates the disadvantage of operating too soon after childbirth. Whenever possible, at least ten or twelve weeks should be allowed to intervene before the operation is performed. In another case the bladder was torn during the procedure of separating it from the fundus, even though the gauze covered finger was used for this purpose. The bladder was unusually thin and friable, and in addition was closely adherent to the uterus, probably as a result of a long-standing cystitis. Such a combination of conditions makes it very easy to injure the bladder, although the accident is usually of no great practical importance. A few stitches, together with catheterization for a few days, was sufficient, in my case, to prevent any unpleasant after-results. Finally, in two cases, small myomata were removed from the fundus before interposing it beneath the bladder.

To sum up the few points which I have especially tried to emphasize in the report of this short series of cases, I would say:

1. No other operation for complete prolapse of the uterus offers as great a probability of permanent cure as does the Watkins-Schauta operation.

2. This operation is a decidedly major one, requiring more skill than the majority of abdominal operations for pelvic disease.

3. Unless the uterus is very small and atrophic, so that it offers no support to the bladder, or unless there is a suspicion of malignancy, it is better to retain it. When hysterectomy is deemed advisable, good results are obtained by performing the operation advocated by Goffe.

4. The cervix should be amputated only when long and hypertrophic, or when it is the seat of ulceration.

5. A well-done perineorrhaphy is an essential for success with the interposition operation.

HÆMOSTASIS, WITH SPECIAL REFERENCE TO ITS EMPLOYMENT IN SURGERY OF THE BRAIN[1]

By CHARLES E. DOWMAN, Jr., M. D., F. A. C. S., Birmingham, Alabama

THE question of hæmostatis in surgery is one which has received a great deal of attention in medical literature. In visiting various surgical clinics, however, one cannot help being impressed with the fact that at times this most important subject, over which every surgeon should have complete mastery, is given far too little attention. Complete hæmostasis and the careful handling of tissues rank in importance with accurate diagnosis and sound surgical judgment; and the tendency on the part of many to sacrifice this phase of surgical technique, for the sake of speed in operating, is greatly to be deplored and should be universally condemned.

As hæmostasis depends largely on the coagulability of blood, it should not be out of place to review briefly one or two of the most acceptable theories of the coagulation of normal blood.

According to Bordet and Delange (1) coagulation of normal blood consists mainly of three steps:

1. As soon as blood escapes from the circulation it undergoes a change which permits coagulation to take place. This stage is very short and very little is known concerning what chemical or physical phenomena occur at this time.

2. During the second step the active coagulation principle, thrombin, is formed. The so-called "coagulation time" depends on the duration of this stage. Bordet and Delange think that thrombin is formed by the reaction which takes place between serozyme and cystozyme in the presence of a soluble calcium salt. Cystozyme is analogous to the thromboplastin of Howell's theory and is derived from the platelets and leucocytes. Serozyme is contained in blood-serum but not in blood-plasma. It may be compared to the prothrombin of Howell's theory.

3. During this stage the thrombin acts on the fibrinogen of the blood and causes coagulation by changing fibrinogen into fibrin, calcium not being required during this stage. The time for this step is about two minutes under favorable conditions.

Lee and Vincent (2) report a series of experiments performed along lines worked out by Bordet and Delange, and agree that the fundamental principles of their theory are correct and apply to the coagulation of normal human blood as well as to the blood of rabbits.

According to Howell's theory (3) a small amount of antithrombin is present in the normal plasma, and is sufficient to bind the prothrombin and render it inactive. Thromboplastin is set free by cell injury (blood-cells, platelets, tissue-cells, etc.), and neutralizes the antithrombin. This frees the prothrombin, which at once combines with calcium to form thrombin. The free thrombin coagulates the fibrinogen, giving the normal clot.

Whipple (4) in a recent paper discusses antithrombin and prothrombin factors in various hæmorrhagic diseases. He accepts Howell's theory of coagulation of normal blood and proves conclusively that hæmorrhagic diseases depend upon the upsetting of the normal antithrombin and prothrombin equilibrium. It is evident that this balance must be extremely delicate and capable of rapid adjustment. When the antithrombin accumulates in excess, the appearance of purpura and bleeding is to be expected, but if it drops to a low level, spontaneous intravascular thrombosis might occur.

[1]Read before the Alabama State Medical Association, April, 1914.

The ordinary methods of hæmostasis are too well understood to permit of discussion. The free use of hæmostatic clamps, ligatures, pressure, hot wet packs, etc., will usually suffice in preventing hæmorrhage during the average operation. The importance of caring for the hæmorrhage *first* in cases of gunshot wounds, ruptured extra-uterine pregnancy, etc., has been so thoroughly impressed on the minds of surgeons as to likewise preclude discussion.

The use of isolated tissue as hæmostatic agents is receiving a great deal of attention in medical literature to-day. From experimental and clinical evidence the use of pieces of muscle, fascia, omentum, etc., in the control of various types of troublesome hæmorrhage is a great advance over the older methods.

In surgery of the brain, the use of small pieces of muscle in the control of troublesome and dangerous hæmorrhage has been practiced for several years. Borchardt in a recent article (5) claims to have used muscle for this purpose for the past seven years. In performing subtemporal decompression operations, he controls the hæmorrhage from the bone-canals with small pieces of the temporal muscle. The method was first practiced by Sir Victor Horsley, and later by Kocher (6) in controlling bleeding during operations for the removal of the Gasserian ganglion. Stieda (7) reports a case of cerebellar exploration during which there was an abundant hæmorrhage from a large venous channel quite near and communicating with the transverse sinus. Control was accomplished only after he had pressed a piece of muscle over the bleeding point. The patient died of respiratory failure on the following day, and at autopsy the small piece of transplanted muscle was found firmly adherent to the vein over the point where the hæmorrhage had occurred. Of interest is the fact that in the central portion of the vein no thrombus had formed. Von Eiselsberg (8) writes also of controlling hæmorrhage during the removal of brain tumors by means of small pieces of fascia. Laewen (9) in a similar manner accomplished hæmostasis by means of free muscle transplants in heart and liver wounds. Cushing frequently uses muscle in this way and demonstrates the excellence of the method in troublesome hæmorrhage from the various venous sinuses of the brain and meninges. His technique consists in spreading out a small piece of muscle on a moist cotton pledget, placing this over the bleeding point, and after a few minutes of slight pressure removing the cotton pledget, leaving the muscle firmly adherent to the vessel from which the hæmorrhage had occurred. I once saw him stop a sharp hæmorrhage from an opening the size of a pinhead in the internal jugular vein with a muscle transplant. The method is of value chiefly in hæmorrhage from veins and venous sinuses, as the pressure in arteries is usually great enough to prevent the muscle from adhering firmly. It would be interesting to learn whether it is the mechanical adhesiveness of muscle or the thromboplastin liberated from the injured muscle cells which is responsible for the perfect results obtained with the method.

The use of isolated tissue seems to be one of the best methods of stopping hæmorrhage from wounds of the liver. Beresnegowsky (10) has recently published the results of his experiments on dogs, proving the value of isolated pieces of omentum in controlling hæmorrhage from the liver and spleen. In the successful experiments the omentum transplant lay adherent to the wounded surface of the liver, no blood-clot being found under the transplanted tissue. After the fat in the omentum had been absorbed there remained a thin connective-tissue capsule over the wounded area.

According to some authors, the hæmostasis is due to chemical activity through the liberation of thromboplastin; according to others, there is a mechanical closure of the lumen of the vessels. Beresnegowsky thinks that the value of omentum as a hæmostatic agent is mechanical and not chemical. In several unsuccessful experiments where the omentum was not sutured tight enough the animals died of hæmorrhage, which proved to his mind that the chemical activity of the omentum is not great. The mechanical value of the omentum consists in filling the liver wounds tightly with the tissue, thus causing it to act as a tampon; or, in surface wounds, in laying it tightly over the bleeding surface, holding it there with proper sutures.

In the control of hæmorrhage from wounds in parenchymatous organs, such as kidney, liver, and spleen, the older methods consisting of gauze tampons, ligatures, and deep sutures are objectionable on account of the degeneration and necrosis of parenchymatous elements which they produce. Waljoschko and Lebedew (11) produced various wounds in the kidneys, liver, and spleen of dogs, and controlled the subsequent hæmorrhage with transplanted pieces of superficial fascia held in place with superficial sutures. They also resected parts of organs and sutured layers of fascia over the raw surfaces. In penetrating injuries the wound canal was

tamponed with fascia. After certain periods of time the animals were killed and the specimens examined microscopically. Their conclusions are as follows:

1. The fascia transplanted on the bleeding surface of an organ acts as a "living tampon" which controls active bleeding and prevents subsequent hæmorrhage.

2. The free transplantation of fascia simplifies the laying of sutures, and avoids the use of deep sutures which would include and compress tissue and are known to cause a certain amount of necrosis of parenchyma.

3. Fascia is an excellent material to use for this purpose in that it does not act as an irritant to an organ which is in itself capable of developing connective tissue.

4. Fascia acts in a way similar to the normal capsule of an organ and, as the pressure exerted is so slight, no atrophy of the gland is produced.

5. A ruptured kidney treated with this method heals perfectly and functionates normally.

6. The substitution of a removed kidney capsule with a sheet of superficial fascia prevents the formation of a secondary scar tissue capsule which would cause a contraction of the whole organ.

There is no branch of surgery in which hæmostasis is more necessary or more difficult than in cranial operations. The scalp receives its arterial blood supply through five large trunks on either side. These break up into innumerable branches which anastomose freely with each other. The venous circulation of the scalp is even more complicated than the arterial. On account of the free communication between the veins of the scalp and those of the diploë, bleeding from this source is often more difficult to combat than that which occurs from the arteries and their branches. The meninges likewise contain a network of vessels.

Every cranial operation will be attended by profuse and alarming hæmorrhage which will not only annoy the operator but will endanger the life of the patient, unless the surgeon has prepared himself to meet in every detail this inevitable ordeal. Not only must he have experience and judgment, but his armamentarium must include the various hæmostatic agents and appliances which have been devised for this special branch of surgery.

The choice and administration of the anæsthetic plays an important rôle in cranial operations. A restless, half anæsthetized patient is usually more or less cyanotic—a condition which will cause an almost uncontrollable venous bleeding. Ether seems to be the anæsthetic of choice, though Horsley prefers chloroform, and Kocher often uses local anæsthesia, preferably with Braun's cocaine-adrenalin solution. Nitrous oxide is distinctly contra-indicated on account of the venous congestion which usually occurs during its administration.

A semi-sitting posture of the patient has a definite controlling effect upon the freedom of hæmorrhage, and on this account is to be preferred. With the patient in this position, however, it is imperative that frequent records of the blood-pressure be made, as a sudden fall would necessitate lowering the patient immediately.

Hæmorrhage from the scalp can usually be controlled by some form of tourniquet. The type described by Cushing is perhaps the most convenient. Heidenhain (12) recommends subcutaneous interlocked mass ligatures around the proposed incision. Kredel (13) uses a modification of this method by tying the mass ligatures upon a flat metal plate. Horsley finds it efficacious to have assistants make manual pressure while he clamps the numerous bleeding points.

The ordinary oozing from the diploic vessels may usually be controlled with Horsley wax (beeswax seven parts, almond oil one part, salicylic acid one part), though at times these vessels may be so large as to require plugging with wooden or ivory pegs, small pieces of absorbent cotton, or pieces of muscle. When the field of operation is near the transverse or longitudinal sinus, dangerous hæmorrhage from abnormally large emissaries connecting the intracranial veins with those of the scalp may occur and tax the patience and ingenuity of the operator. Cases have been reported where the hæmorrhage from the bone assumed such dangerous proportions as to necessitate the temporary ligation of one or both carotid arteries.

In performing cerebellar exploration on patients with marked intracranial pressure, one often finds the occipital muscles covered with large lakes of venous blood. To attempt to proceed would lead to an uncontrollable hæmorrhage which would probably endanger the patient's life. In such a condition it becomes necessary first to relieve the intracranial pressure by tapping the lateral ventricle through a small trephine opening in the parieto-occipital region. As the cerebrospinal fluid escapes, the venous lakes collapse and one can usually continue the operation without danger from this source.

On opening the dura, hæmorrhage from the various branches of the meningeal arteries can

be prevented by means of fine silver-wire clips applied with suitably devised forceps, as described by Cushing. These clips may also be used on the middle meningeal artery as it emerges from the foramen spinosum, during operations on the Gasserian ganglion, and on the cortical vessels before incising the brain. The ease of application and their effectiveness make them much more desirable than sutures.

Among the most valuable of all hæmostatic agents in cranial operations are small cotton pledgets wrung out of hot salt solution. These are laid on the various oozing points and hasten coagulation. Mention has already been made of the value of pieces of muscle in the control of troublesome bleeding.

Should a considerable hæmorrhage occur from one of the venous sinuses, it is usually advisable to control it in the quickest way possible and to postpone the further steps of the operation until another time. By exercising this caution in such cases, operative deaths may often be prevented. The justification of a two-stage operation for tumors of the brain lies in the fact that the laying down of a bone flap is usually attended by excessive hæmorrhage.

Subsequent hæmorrhage in cranial operations may usually be prevented by exercising care in effecting the closures. This is best done by several layers of interrupted fine silk sutures. Such sutures act as ligatures in addition to aiding the approximation of the edges of the wound.

In conclusion I wish to emphasize the following facts:

1. That complete hæmostasis is one of the most important phases of surgical technique.
2. That the type of operative surgery which sacrifices refinement in technique for the sake of speed should be condemned.
3. That the use of various tissues as hæmostatic agents has a distinct field of usefulness.
4. That hæmorrhage during cranial operations is most troublesome and dangerous, and requires for its control the exercise of patience, ingenuity, and sound judgment on the part of the operator, in addition to the employment of the various hæmostatic agents and appliances known to surgery.

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A TWO-EYED ANEURISM NEEDLE

By GEORGE T. TYLER, A. M., M. D., Greenville, South Carolina

THE necessity of doubly ligating blood-vessels or other tissues, or of placing two ligatures and dividing between them, occurs in a great deal of our operative work. In the ordinary aneurism needle threaded with a double ligature, one part often becomes twisted around its fellow, requiring extra time to separate and frequently causing annoyance in doing so. It has occurred to me that our anuerism and pedicle needles might be made with two eyes, placed side by side. With each eye threaded two ligatures could be introduced simultaneously and kept separate. This needle can still serve the purpose of the original type by threading only one eye.

The accompanying illustration explains itself.

MALIGNANT DISEASE OF THE RETAINED TESTICLE

With Report of a Case

By ARTHUR PARKER BUTT, M. D., F. A. C. S., Davis, West Virginia, and AARON ARKIN, A. M., Ph. D. M. D., West Virginia University, Morgantown

(From Pathological Laboratory of West Virginia University.)

IN a recent very comprehensive article on this subject[1] Dr. Kenneth Bulkley states that there had never been a collective study of the literature on the subject of malignant tumors of the testicles situated within the abdominal cavity. He was able to collect but 57 cases; to these he added two cases coming under his own observation. Dr. Bulkley also states that these tumors occur but once in 60,000 male hospital entries.

With these statements before us it seems well worth while to report all cases.

Dr. Bulkley's paper is so complete and so recent that it seems useless to take up the subject other than to report one case with a very few comments.

Patient was referred by Dr. John T. Huff of Parsons. Age 48, weight 145; thinks he has neither lost nor gained recently. Occupation, farmer; appetite good, sleeps well. Mother and one maternal aunt died of tuberculosis, father of old age. Two deaths from cancer on father's side. Married, no children; claims to have led a vigorous sexual life until recently. Has seen that his health is failing during past year. Seeks relief from "spells with his stomach." Has had an occasional "spell" for past three or four years, three within the past nine months. Nearly all of them come on during the night; usually they come suddenly; and he often vomits before getting relief. After vomiting, is always relieved. Sometimes these attacks of pain last several hours. At first the pain was on right side, lately it has been on left.

Previous history negative. About six months ago he discovered an enlargement of the abdomen. Examination showed a man of light build, a very scanty moustache, practically no beard, and a voice rather bordering on the feminine type. Scrotum small, penis rather undersized, no testicles in scrotum or inguinal canal. Inguinal glands not enlarged. A large mass was found in left lower abdomen, hard, smooth, slightly movable. Patient was told that he had a tumor, probably malignant, of the left testicle. Consent was asked to remove right testicle no matter what its condition. Operation was performed by Dr. Butt at the Allegheny Heights Hospital on December 30, 1913. Spinal (stovaine) anæsthesia supplemented by ether. Incision over left rectus, muscle displaced towards median line. The tumor in appearance and location reminded one of an ovarian growth. Surface smooth, glistening, covered with peritoneum. Pedicle about two inches broad, attached in region of left internal ring. Very slight attachment to bladder and bowel. Tumor weighed three and one-half pounds, greatest circumference 20½ inches, lesser 14½. Right testicle was removed from deep in pelvis. No measurements were taken but it was perhaps 25 per cent larger than normal. Convalescence was delayed by a right otitis media. This occurred on the twelfth day, drum was incised and ear had almost ceased to discharge when he left hospital. On the sixteenth day after operation he began to suffer with pain in the calf of his left leg. No pain, no swelling, until he was up walking. Left hospital on the thirty-second day, well with the exception of phlebitis of left leg. One month after this he wrote that he was not feeling well, legs wollen, unable to work. A month later he presented himself for examination. With exception of condition noted in left leg he seemed in excellent health. Had gained ten pounds. June 18th, he wrote me that his general health was "not so well," weighs six pounds more than when operated, has some pain in back, is doing light work, is unable to get his bowels regulated.

Diagnosis: Notwithstanding the rarity of this disease, there should be little trouble in making a diagnosis if the absence of one or both testicles is noted. It seems from the literature on the subject that many men have failed to note this. This is due in some measure to the natural desire of the patient to conceal his deformity. This was the case with our patient. He had to be practically forced to uncover his scrotum.

Prognosis. According to Bulkley, of 59 cases operated on only three are known to be alive and well after two years.

Treatment. Excision of the retained testicle upon the onset of even the vaguest symptoms.

Microscopic examination. (Dr. Arkin.) Scattered throughout the tumor section are masses of large cells, with pale vesicular nuclei, some of which show distinct nucleoli and a clear cytoplasm. Many of these cells are irregularly arranged in solid masses forming nests or alveoli which anastomose with each other, giving to the tumor the appearance of a scirrhous type. In other areas these large cells are arranged in more or less distinct tubule formations. In still other areas, the carcinoma cells have infiltrated between the connective-tissue fibers, forming long cords or chains of cells. Mitotic figures can be distinguished in some of these cells.

The interstitial tissue is rich in darkly staining small round cells and numerous spindle cells of a connective-tissue type, between which the large round or polyhedral cancer cells are scattered. In a few places there are aggregations of lymphoid cells resembling very closely normal lymphoid tissue. In one or two areas, the dark small round cells are arranged about small blood-vessels, presenting the appearance of a peritheliomatous proliferation.

Scattered through the section are found round or oval pale hyaline-like areas, some of which are solid, others presenting small lumina. A few of

[1] Surg., Gynec., & Obst., 1913, December.

these lumina are filled with calcareous deposits. These areas, in all probability, represent atrophied seminiferous tubules which have undergone a fibrosis. In the connective tissue, can be seen, here and there, typical giant-cells of the Langhans type, containing from six to twenty nuclei. The nuclei in these cells are arranged about the periphery, although in some the nuclei fill most of the cell, depending upon the direction in which the cell was cut. In some portions of the tumor these cells are more numerous than in others, and they are found in the connective tissue.

The tumor is surrounded by a definite capsule of connective tissue, which is irregularly infiltrated with many dark round cells of a sarcomatous type, together with a few large round or polyhedral cells with pale nuclei. The small round cells form solid cords two or three cells in thickness, or else chains of two to six or eight cells lying between the connective-tissue fibers. The carcinoma cells form anastomosing bands which lie between the small round cells. These are arranged parallel to the surface and seem to have infiltrated the loose connective tissue between the capsule and the tumor, forming a distinct zone between the two. They are especially marked about some of the blood-vessels, and seem to have followed the course of the lymphatics.

The tumor shows very little evidence of necrosis, as the cells in the central portion stain quite distinctly. There is no bone tissue, cartilage, muscle, or cyst formation in any portion of the tumor.

The section sent as right testicle presents no normal testicular tissue. Scattered throughout the section are many round or oval areas which stain faintly and have a hyaline appearance. They contain a few elongated connective-tissue nuclei. These are evidently remnants of the seminiferous tubules. No normal seminiferous tubules are visible in any portion of the section. The fibrosed tubules are much more widely separated than in the normal testicle. The great part of the section consists of diffuse masses of large round or polyhedral cells which contain large pale nuclei with fine chromatin granules. These cells resemble the ones described in the tumor sections. The cancer-cells have a tendency to alveolar arrangement. Between these cells are many proliferating connective-tissue cells and numerous dark small round cells. The cancer-cells stain more deeply about the larger vessels, and it is here also that the small round cells are most numerous. There are in this section, just as were described in the tumor section, several lymphoid accumulations. Likewise, a few giant-cells, resembling those described in the tumor, are present in the connective tissue. The capsule is infiltrated with many small round cells, and connective-tissue cells in various stages of development.

The section sent as left testicle shows the cancer-cells quite numerous, with a greater tendency to alveolar arrangement. Some of these alveoli are entirely surrounded by connective tissue; most of them anastomose with one another. There are several large solid masses of these cancer-cells in the section, which have the appearance of a medullary carcinoma. These masses show no evidence of necrosis, and seem to be growing rapidly. They are surrounded by an indistinct connective-tissue stroma, through which masses of cells are penetrating in every direction. The connective-tissue stroma contains many small round cells. There are several large lymphoid accumulations in this section also. Just beneath the capsule, which is not greatly thickened, are numerous darkly stained small round cells. A few giant-cells can be found in this section also.

There is no normal tissue in the section sent as epididymis. The vas cannot be found in this section. There are a few irregularly shaped compressed tubules, lined with low columnar epithelium, in one corner of the section. These are the only evidence of tubules in the epididymis. Near these can be seen several compressed canals of the rete testis. The tissue is entirely infiltrated with solid masses of cancer-cells, separated by proliferating connective tissue, which contains many small round cells and quite a few giant-cells of the Langhans type. The section also contains several lymphoid areas. In most respects it resembles the tumor section described above.

The tumor represents a case of sarcocarcinoma of double undescended testicles. The carcinomatous portion predominates, and the connective tissue shows evidence of sarcomatous proliferation with large numbers of small round cells. In addition, there are also giant-cells present, making the tumor an unusual one. There are lymphoid follicles present in the tumor, an observation which has been made in many mixed tumors of the testicle. The mixed tumor has involved both of the undescended testicles and the adjacent tissues.

(A complete pathological study of this case will be published later.)

SURGICAL HELPS

By G. P. COOPERNAIL, M. D., Bedford, New York

A PRACTICAL CAUTERY. For several years I have been using the cautery that I am about to describe. The cautery irons that I wish to advocate are the small size soldering irons. They can be found in any of the large department stores. The ends of the irons can be shaped as you wish with a coarse file.

The heating apparatus is the gas blow-torch used by plumbers or painters for burning off old paint. They are furnished with soldering iron attachments. The fuel used in the torch is the commercial gasoline. Operating the torch is very simple. Connected with the torch is a small air-pump which gives a forced feed. A few strokes of the pump will give you a pressure that will last for a half-hour heating.

Under the burner is a priming cup which is filled with gasoline; this heats the burner so as to convert the gasoline into a gas. I use alcohol in the priming cup, as there is an odor to the burning gasoline. After the cup is burnt dry open the needle valve and light the gas.

The size of the flame can be regulated by the needle valve. This gives a very hot flame and will heat the irons in a very few minutes. It will heat much quicker than the Bunsen gas-burner and can be carried and used in places were there is no gas. It is light and can be easily carried in your bag. Another good feature is, you can always rely upon it.

The impulse to write this brief article came to me a few months ago when I saw a celebrated English surgeon demonstrating one of his intestinal operations. That morning, to be sure of having one of the Paquelin cauteries in good working order, the operating-room nurse tried out three of them and found at the time all would work; but at operation none would work.

Paper clips as spools for linen or silk sutures. For over ten years I have been using the ordinary paper clips in place of the glass spool for linen or silk sutures.

They are cheap and more convenient than the glass spools. There is no danger of their breaking, so they can be boiled with the instruments. Another advantage is, the ends of the sutures can be caught in the center of the clips so it will not unwind when not in use. After operating I dry them out in a drying oven with the instruments. The last few years the tendency is to make most of our surgical instruments with screw locks, so it is almost impossible to get them dry in the lock. A few minutes in a hot air oven will dry them and prevent rusting.

Patches for repairing rubber gloves and how to put them on. For the past ten years I have been having my nurses use small, round patches for mending rubber gloves.

Before I used the round patches one day I noticed our operating-room nurse trying to cut out patches with a pair of scissors. The rubber was not easy to cut and after the patches were cut out they had many sharp corners to work loose. One could see a round patch would be much better.

The idea came to me to punch them out with a gun-wad punch. The punches are made in several sizes.

The patches can be punched out of the gauntlet of an old glove. With a hammer and a block of hard wood one can in a few minutes punch out enough patches to last a long time. They make an ideal patch, without corners.

Clean the patch and glove with gasoline. Stick the patch on a piece of cardboard with two pins near the edge of the patch. This will prevent the patch from curling up when the cement is drying. Let the cement almost dry before pressing the patch over the hole.

It is better to give both the patch and the glove two coats of cement, letting the first dry before applying the second. After the patch is firmly pressed on, dust with talcum powder so as to prevent the cement outside of the patch from sticking.

A test tube is a great help in patching the fingers of the gloves. Don't forget to put the patches on the inside of the gloves. I remember, when doing a strangulated hernia at night, that a patch came off and was left in the wound. It healed by primary union, but the fifth week one end of the incision broke down and in exploring the wound I found a rubber patch in the bottom of it. This would not have happened if the patch had been on the inside of the glove. I am glad to say it was not one of my round patches.

TRANSACTIONS OF SOCIETIES

CHICAGO GYNECOLOGICAL SOCIETY

THE REGULAR MONTHLY MEETING OF THE CHICAGO GYNECOLOGICAL SOCIETY WAS HELD APRIL 17, 1914, WITH THE PRESIDENT OF THE SOCIETY, DR. FRANK W. LYNCH, OCCUPYING THE CHAIR

DR. MARK GOLDSTINE presented a paper under the heading of "Report of Cases."

REPORTS OF THREE CASES OF ABNORMAL DEVELOPMENT OF FEMALE GENERATIVE ORGANS

CASE 1. Mrs. Rose R., 33 years old. Menses began at 14 years, 28-day type, duration 4 to 5 days. Flow very heavy and with severe pain. Last menstruation March 17, 1912. December 27, 1912, gave birth to 8½-pound baby, which was her first pregnancy. On December 31st she had a severe chill with rise of temperature and severe pain in lower abdomen and was very ill for a number of days. When I saw her first on January 28, 1913, she presented a typical picture of puerpual sepsis. There was a large tender mass on left side of abdomen, from the pelvic brim to about the level of the anterior superior spine and one inch to the left of the median line, apparently no exudate to the right whatever; and these findings were the same on vaginal examination. She was admitted to the Wesley Memorial Hospital January 29, 1913, and remained in the hospital 44 days, until March 13, 1913. On leaving the hospital there still persisted a considerable mass on left side.

Examination after admission to hospital. Abdominal examination same as above. Vaginal examination: slight laceration of perineum; just inside vulva there presented itself a very firm septum, dividing the vagina into two equal compartments It was about ¼ inch thick at vulva and about ½ inch at its posterior attachment; it was of same structure as vagina; no opening in septum between two vaginæ; each vagina contained a cervix, one normal in appearance and the other showing the effects of recent childbirth A probe was passed into each and on right side went in about three and one-half inches, and on left about four and one-half inches. Patient was readmitted to hospital May 22, 1913. The mass in left side only trifle smaller. An abdominal section was done; on the left side was a fairly large tubo-ovarian abscess; the uterus, tube and ovary were removed; the blood supply was entirely from left side; a space of three inches separated above uterus from another on the right; the uterus with its tube and ovary on the right side received its blood supply entirely from the right side. No apparent connection between the two uteri. The bladder and urethra were normal in size and position, intestines normal and in position. Patient is now well and has menstruated regularly since operation; very little pain and menstruation not nearly so profuse. As far as the writer can ascertain, this is the only case recorded in literature where there were two distinct uteri.

CASE 2. Mrs. W., age 30. married 8 years; 2 children, no miscarriages. Last baby born in November, 1913. Menstruation began at 15. Regular 28-day type and was exceptionally profuse and lasted 8 to 9 days. Menstruated regularly every month during her pregnancies but not as heavy as usual, and also during lactation. Recoveries from childbirth uneventful. Had two attacks of appendicitis. Severe backache for years. Abdominal examination negative except for tenderness over appendix and lower abdomen. Vaginal examination: incomplete laceration of perineum. Cervix large, external os admits a finger, some laceration. Bimanual examination, mass in left side about the size of a normal uterus and same on right, with a space of about 4 inches, directly in median line where no structures could be palpated, where both examining hands could easily be brought together. An abdominal section was performed and showed two uteri normal in size and appearance and about 5 inches apart, each with a normal tube and ovary on the left and right sides respectively. No evidence of blood supply or appendages on the inner sides of the two uteri; both lay to the extreme sides of the pelvis and were retroflexed. A large heavy fold of peritoneum in the form of a broad ligament about one inch wide connected the bladder with the sigmoid and upper part of rectum and lay between the two uteri. The bladder was very large. The external os was open and just inside the cervix the canal divided into two divisions, one canal going to each uterus.

CASE 3. Miss Blanche H., age 18. Family history negative. Ordinary diseases of childhood. Has had severe headaches for last 4 to 5 years. Has never menstruated. Nothing like menstrual cycle in patient's history. Amenorrhœa. Vaginal examination: labia and clitoris poorly developed. Normal urethra. Non-perforated hymen. Rectal examination: no evidence of vagina or vaginal vault, no cervix to be felt

Symphysis pubis very broad like male pelvis and easily reached from rectum. Bimanual examination with finger in rectum: no uterus could be felt and no definite pelvic structures felt.

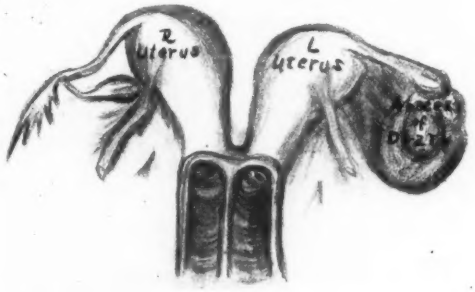
Exploratory laparotomy. On right side cystic ovary about size of hen's egg, with a normal tube and an accessory tube attached about 1½ inches from the fimbriated end and with a fimbriated end of its own; this tube was 2 inches in length and just slightly smaller in its circumference than the tube it was attached to. The main tube terminated in a small embryological structure resembling a uterus; this was about 1½ inches long, ½ inch wide and the same in thickness; this terminates in the vesical peritoneum posterior to the bladder. Broad ligature normal. On left side was found the same as on right, but only one tube and a normal ovary and same structure resembling uterus. No connection between two sides. No cervix on either uterus, no vaginal vault. Bladder and intestines apparently normal. This case is a very unique one.

DR. WALTER C. JONES followed with a paper entitled: "Experimental Ligation of One Ureter with Application of Results to Clinical Gynecology—Inguaural Thesis."

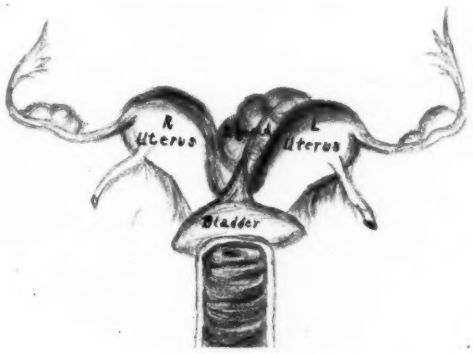
DR. A. BELCHAM KEYES read a paper entitled: "Mastitis Lactantia; Etiology, Behavior, and Treatment." (See p. 364.)

DISCUSSION

DR. N. S. HEANEY: I was very much interested in Dr. Keyes' paper because it referred to a subject to which I pay a great deal of attention. It has been a matter of luck, rather than careful attention, I believe, that I have had very few abscesses—in fact only two, and those were unfortunate enough to have been doctors' wives. The obstetrician as a rule assumes no responsibility for the occurrence of breast-abscess, in which he is most properly justified, except in this, that he is responsible if the nurses who are attending his patients are not properly instructed in the attention to the breasts. One thing that has always appeared to me as especially dangerous is the handling of the breast by the hand of the nurse, who at one moment takes up a vulvar pad and puts it on a chair or window when she goes to answer the bell of another patient, and the next minute brings in the child to the breast and gets the nipple to work so the child can grasp it. If the nurse's hand becomes contaminated with the secretion of the pad, she is absolutely dangerous to the breast of the mother.



Double uterus. One ovary and one tube to each uterus. Two cervices separated by partitions.



Bicornate uterus. One ovary and tube to each horn. Bladder attached to sigmoid by reflection of peritoneum.

DR. PADDOCK: I do not know that I can add anything to this interesting paper. Abscesses of the breast, I think, are becoming rare. As we become more proficient in the handling of our obstetrical cases, we who are especially giving more attention to these cases see very few cases in our own practice. I thought I would never see another case; and yet within the last few months I have had two; and one of them is unique, as far as the cases I have seen are concerned, in that on the ninth day the patient suffered a great deal of pain in the left breast, a mass formed, filling up practically at least a quarter of the right side of the breast, with some redness of the skin, high temperature and chills. The temperature was 105° when I saw her, but there was no fluctuation. The usual treatment was pursued—absolute rest, ice pack, and later, hot fomentations. This was continued forty-eight hours. The temperature would go up every afternoon very high, with chills. Finally it was decided the best thing to do was to open the abscess. I made a good free opening, making an opening large enough to pass my finger in and get the pus. I inserted my finger and found it to be a hard mass, not broken down. No culture was taken to determine just what the mass was, but there was no discharge. The tube was taken out in about 48 hours. There was nothing except the secretion you get with any wound of that sort, with the temperature and pulse normal. It went along this way 72 hours. Suddenly there was another pain, another rise of temperature and chills in the other breast—the same identical picture. I waited, hoping perhaps I might be mistaken. It might not have been that lump that caused the abscess. I waited 24 to 48 hours more: no fluctuation. I opened that other lump, and did the same operation. The temperature dropped in six hours to normal and remained normal, and resolution took place without any discharge. The question is, when to know that we have some occasion for operation. Unless you have the distinct

fluctuation it is sometimes difficult to say just when to open, or whether you have a difficult abscess to combat or not. I don't know in this case whether resolution would have gone on without opening. On the other hand, I do not believe we find as many cases as we did and I think the whole treatment is in the prophylaxis, the treatment before and during the first few days of the puerperium.

DR. KEYES (closing the discussion):

I feel that we do a great deal of good by making a free incision and drainage in a large number of cases. We let out a lot of serous material and the temperature drops to normal. The indication is to let out that material and yet there is no telling whether it has undergone resolution. The fact that there was a hydro-exudate there is almost as much cause for it being emptied as if it were pus. The infection undoubtedly may cause a very marked amount of disturbance, and the marked frequency of the pus is the greatest perhaps in the lymphatic infection. I firmly believe in cases of deep hardness that the indication is for early and free incision, and as Dr. Paddock correctly stated, I believe there should be deep drainage.

CORRESPONDENCE

Dr. Franklin H. Martin,
Chicago.

My dear Doctor: In SURGERY, GYNECOLOGY AND OBSTETRICS, for June, 1914, Department of Technique, Dr. O. H. Stanley, of Concord, N. H., writes his experiences with pituitrin in abdominal surgery, and is anxious to know of the experiences of others. Having a little data, I am pleased to submit the following results:

I have used pituitrin as a routine post-operative treatment in seventy-five laparotomies; namely, gall-stones, obstruction of the bowel due to adhesions, post-operative adhesions, appendicitis, hysterectomies, ovarian cysts, ectopic pregnancies, pyosalpinx, and others, with the most gratifying results. Pituitrin has a stimulating effect on the heart muscle and the bladder, as well as its stimulation of peristalsis. Because of its satisfactory action on the heart I have discontinued the use of strychnine and digitalin, as I found that the pituitrin gave the same effects.

My method of administration is to give 1 ccm. per hypo as soon as the patient comes off the table. This is repeated at intervals of four hours — oftener, if necessary, though I have not had occasion to do so, except in a case of fæcal impaction, which I did not operate. In this case I gave 1 ccm. every two hours, assisted by high colonic flushings, and obtained gratifying results.

I have not had to catheterize more than two cases, and these were cases of malignancy with involvement of the bladder. Following cholecystectomy I have had good results, and I am inclined to think that it has prevented that most serious complication, namely, acute dilatation of the stomach, so much dreaded following these operations.

In none of the above cases did paresis of the bowels occur.

From this experience alone I have come to the conclusion that pituitrin is a great adjuvant to abdominal surgery. Given in 1 ccm. doses following a laparotomy, it is all that is necessary in the way of medical treatment, as it not only stimulates the functions of the heart, bladder, and intestines, but tends to prevent the many complications due to adhesions and paresis following an abdominal operation.

Yours fraternally,
EVAN H. M. GRIFFITHS, M. D.

BOOK REVIEWS

A CRITIQUE OF NEW BOOKS IN GYNECOLOGY AND OBSTETRICS

By GEORGE GELLHORN, M. D., Saint Louis, Missouri

THIS textbook has grown out of the authors' "Diagnosis of Diseases of Women," which was the first and for a time the only American work on gynecological diagnosis.[1] The good features which distinguished this book reappear in the large volume before us. The author recognizes the principle that the correct interpretation of symptoms rests primarily upon a thorough knowledge of the morbid anatomy, and he therefore pays particular attention to a detailed description of both the macroscopic and microscopic structure of the affected parts.

The general practitioner will welcome the chapters on conservative methods of treatment, such as douches, baths, massage, diet, and tampons, for these non-operative measures have not received their due share of consideration in textbooks and in practice which they rightly deserve. In these days when gynecology is in danger of becoming merely a surgical specialty, the gynecologist, too, should make himself conversant with every non-operative measure which may promise relief. For this reason, pessaries might have been given a little more space than the author reserves for them. For prolapse of the uterus when operation is deemed inadvisable, the author recommends the old cup and stem pessary attached to an abdominal support. The reviewer would venture the opinion that the Menge and Loehlein pessaries have rendered the McIntosh pessary obsolete.

In the matter on hygiene, dress, and exercise, the author shows himself in line with the best teachings of the day. This chapter, short as it is, will be of greatest value to the practitioner in that it will enable him to forestall disease by his wise counsel.

The chapter on post-operative complications and their treatment will doubtless be consulted with advantage by many and help in numerous instances to turn the scale in favor of the patient.

This review cannot be closed without a word of appreciation of the chapter on diseases of the urinary system. This field is no longer on the borderline between gynecology and surgery. The genital and urinary systems in the female are so closely allied both topographically and developmentally that familiarity with this topic has become an absolute necessity to the modern gynecologist.

May we not ask the author to eliminate biblical references in future editions of this book? If, for example, he believes that pregnancy may occur after the menopause (p. 68), he should be able to cite more recent cases than that of "Abraham who was one hundred years of age and Sarah ninety when their child was born."

In a work of this size, debatable points are bound to occur. One can, for instance, hardly agree with the author when he dismisses, in less than four lines, the subject of spinal anæsthesia notwithstanding the fact that this method has become the sovereign one in gynecologic operations in Germany and France and is just now having a renaissance in this country. But such points of difference are easily overlooked in weighing the value of the entire book, which has been written in so concise a manner and which so clearly portrays the author's qualifications as an excellent teacher that we do not hesitate to warmly recommend this textbook to the profession.

WE greet an old friend in this new edition of a work which in the high tide of modern textbooks has preserved its well-merited popularity.[2] The rapid changes which are taking place in gynecology have imposed upon the author the duty to rewrite many chapters; but by rigid rearrangement and condensation, he has found space for much new matter without enlarging the volume. The simplicity and clearness of diction renders the study of the book both easy and attractive to the reader, and as the book addresses itself primarily to the student, mooted questions have been left out of consideration. For the same reason, bibliographic references have been restricted.

To the specialist the volume possesses a particular attraction in the profusion of original illustrations, many of which are in color. The reviewer gladly acknowledges his indebtedness for many a point in operative technique, and he believes that others, too, will frequently find it helpful to consult this book for details of simplification and elegance. In the development of American gynecology, Dudley ranks foremost as a master of plastic methods of all kinds. His operation for pathologic anteflexion of the uterus, the reconstruction of a urethra, his procedure for ureterovaginal fistula, and the operation for certain

[1] Diseases of Women — A Treatise for Students and Practitioners. By Palmer Findley, B. S. M. D. Philadelphia and New York. Lea & Febinger, 1913.

[2] The Principles and Practice of Gynecology. By E. C. Dudley, A. M., M. D., Sixth Edition. Philadelphia and New York: Lea & Febiger, 1913.

forms of urinary incontinence form only a partial list of the author's original contributions which are incorporated in this textbook. It is safe to predict that the seventh edition of this work will be but a question of time.

THIS book [1] has a number of features which are apt to make it attractive to teachers in nurses' training schools. The descriptions are, for the most part, clear and precise, and there is appended to each chapter a discussion on the function of the respective organs. In this manner the author has, in a very felicitous fashion, combined the study of anatomy and physiology of the human body — the best method, indeed, in which these two subjects should be treated. There is, also, at the end of each chapter a list of questions as a means of reviewing the subject.

[1] ANATOMY AND PHYSIOLOGY — A TEXTBOOK FOR NURSES. By John Forsyth Little, M.D. The Nurses' Textbook Series. Philadelphia and New York: Lea & Febiger, 1914.

The book has, however, in common with most textbooks on anatomy for nurses, the defect that it is much too long. A subject which the average medical student with all his required preparatory studies is expected to cover within a year or two, the nurses, most of whom possess but an indifferent preliminary education, are supposed to imbibe in about eight months. The value to a nurse of instruction about karyokinesis of Ascaris megalocephala is, at least, open to discussion, and prickle, transitional, and neuro-epithelial cells will, I fear, prove merely a burden to her memory which might contain more useful information.

Conversely, the discussion of the female genitalia and their functions might well be more extensive, for in this field the nurse needs more knowledge for her own benefit and that of her clients.

Print and paper are very good, but the illustrations are not in keeping with the excellency of American medical illustrations, which have set an example to the rest of the world.

BOOKS RECEIVED

Books received are acknowledged in this department, and such acknowledgment must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers and as space permits.

DIAGNOSTICS OF FUNDUS OCULI. Vol. I, with Index; Vols. II and III with stereograms. By Edward L. Oatman, M. D. Troy, New York: The Southworth Company, 1913.

PRACTICE OF SURGERY. By Russell Howard. Price $5.50. Philadelphia: J. B. Lippincott Company.

TEN SEX TALKS TO BOYS. By I. D. Steinhardt, M. D. Philadelphia and London: J. B. Lippincott Company, 1914.

ANATOMY AND PHYSIOLOGY OF THE EYE AND APPENDAGES. By John Welsh Croskey, M. D. Published by the author.

PHYSIOLOGIE NORMALE ET PATHOLOGIQUE DES REINS. By L. Ambard, M. D. Paris: E. Gittler, Editeur.

LA STASE INTESTINALE CHRONIQUE. Par le Docteur E. Sorrel. Paris: G. Steinheil, Editeur, 1914.

PRACTICAL THERAPEUTICS. Second Edition. By Daniel M. Hoyt, M. D. Price $5.00. St. Louis: C. V. Mosby Company, 1914.

SOME AMERICAN MEDICAL BOTANISTS. By Howard A. Kelly, M. D., LL. D. Troy, New York: The Southworth Company, 1914.

RECENT STUDIES OF TUBERCULOSIS. St. Louis: Interstate Medical Journal Company, 1914.

MEDICAL AND SURGICAL REPORTS OF THE EPISCOPAL HOSPITAL OF PHILADELPHIA. Philadelphia: Wm. J. Dornan, 1914.

NOTIONS PRATIQUES D'ELECTROTHERAPIE APPLIQUÉE À L'UROLOGIE. Par le Docteur Denis Courtade. Paris: F. Gittler, Editeur, 1914.

BEITRÄGE ZUR KLINISCHEN CHIRURGIE (FESTSCHRIFT). Tübingen, Germany: H. Laupp'schen, 1914.

COLLECTED PAPERS BY THE STAFF OF ST. MARY'S HOSPITAL, MAYO CLINIC, (1913), Rochester, Minnesota. Philadelphia and London: W. B. Saunders Company, 1914.

KURZGEFASSTER HANDBUCH DER GESAMTEN FRAUENHEILKUNDE, GYNAKOLOGIE UND GEBURTSHILFE FÜR DEN PRAKTISCHEN ARTZ. By Dr. W. Leipmann. Band II, Pathologische Anatomie und Histologie der Weiblichen Genitalorgane in Kurzgefasster Darstellung. By Oskar Frankl. Leipzig, Germany: F. C. W. Vogel, 1914.

LEHRBUCH DER HEBAMMENKUNST. Fifteenth Edition, enlarged and revised. By Bernhard Sigmund Schultze. Leipzig: Wilhelm Engelmann, 1914.